Multisensory Integration of Social Information in Adult Aging

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In memory of my dad Lucjan, whom I promised the day before his fatal stroke in 1995, I will pursue an academic career.

Contents

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text. None of this work has been submitted in application for a degree or professional qualification in any other institution or university.

(Edyta Monika Hunter)

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Abstract

Efficient navigation of our social world depends on the generation, interpretation and combination of social signals within different sensory systems. However, the influence of adult aging on cross-modal integration of emotional stimuli remains poorly understood. Therefore, the aim of this PhD thesis is to understand the integration of visual and auditory cues in social situations and how this is associated with other factors important for successful social interaction such as recognising emotions or understanding the mental states of others. A series of eight experiments were designed to compare the performance of younger and older adults on tasks related to multisensory integration and social cognition. Results suggest that older adults are significantly less accurate at correctly identifying emotions from one modality (faces or voices alone) but perform as well as younger adults on tasks where congruent auditory and visual emotional information are presented concurrently. Therefore, older adults appear to benefit from congruent multisensory information. In contrast, older adults are poorer than younger adults at detecting incongruency from different sensory modalities involved in decoding cues to deception, sarcasm or masking of emotions. It was also found that age differences in the processing of relevant and irrelevant visual and auditory social information might be related to changes in gaze behaviour. A further study demonstrated that the changes in behaviour and social interaction often reported in patients post-stroke might relate to problems in integrating the cross-modal social information. The pattern of findings is discussed in relation to social, emotional, neuropsychological and cognitive theories.

Publication from this thesis

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[1] Permission to include the paper in this thesis has been obtained.

Chapter 1: General Introduction

The main aim of this thesis is to explore whether understanding the mental and emotional states of others could be enhanced through multisensory integration in adult aging. The idea of this thesis deeply reflects my scientific credo postulated by Aristotle in *Metaphysics* that *'the whole is more than the sum of its parts'*. Throughout this thesis, examples will be provided to illustrate that when two sensory cues occur at the same time and space, they can produce a greater benefit in social interactions than the same cues presented separately, hence postulating that '*the whole is more'*. I will use multidisciplinary approaches ranging from neuropsychological, social, psychophysical and cognitive theories to expand our understanding of the role of multisensory integration in social situations in healthy aging and stroke patients. This first chapter will discuss the basic background related to multisensory integration and emotional processing in adult aging. The literature on the effects of age on cross-modal emotion perception will be reviewed in more detail in Chapter 2.

Emotions

The most challenging frontiers in modern affective science relate to the definition of what are emotions, how to measure emotions and how to bridge the gap between Cartesian mentalism and the evolutionary perspective view of emotions (de Gelder, 2010). This thesis does not directly address these very intriguing issues, and adopts the dominant view of emotion in psychology postulated firstly by Darwin (1872) and further developed by Ekman (1992) which view emotions as '*complex, organized and speedy responses'* (Price, 2005, p.101) and a product of evolution to manage social situations. In line with this view, understanding emotions are necessary for the successful navigation of the social world, social interactions and relationships. For instance, misunderstanding social cues portrayed on the face or voice might lead to inappropriate social behaviour.

Therefore, in this project, emotions will be viewed as 'basic' and that they '*evolved through their adaptive value in dealing with fundamental life-tasks'* (Ekman, 1992, p.192). These basic emotions (sadness, fear, anger, disgust, happiness and surprise, see also Figure 1.1) are also believed to be universal and can be recognized regardless of race or culture (Ekman, 1992). According to Ekman, a single emotion portrayed either on the face or in the voice has its own distinctive signal or features which could be easily distinguished from other types of emotions. Ekman refers to these distinctive characteristics as an '*emotion family*' postulating that each particular type of emotion will activate certain muscular patterns specific for only one family of emotions. He argues: '*in all members of the anger family the brows are lowered and drawn together, the upper eyelid is raised and the muscle in the lips is tightened (…) Variations in the family of anger facial expressions are hypothesised to reflect whether or not the anger is controlled, whether the anger is simulated or spontaneous, and the specifics of the event which provoked anger'* (Ekman, 1992, p.233).

Figure 1.1. Ekman's examples of basic emotions from top left: surprise, fear and disgust, bottom left: sadness, anger and happiness.

Although faces are thought to be the most important source of social information (Itier & Batty, 2009), understanding emotions in the voices is also crucial for social perception. Therefore, another aim of this thesis is to investigate how younger and older adults decode basic emotions from faces using Ekman and Friesen's facial stimuli (Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002) and voice prosody using non-verbal affective stimuli (Belin, Fillion-Bilodeau, & Gosselin, 2008). It is postulated that non-verbal affective bursts have unique representative signals for each family of emotional expression, as in the case of faces (Belin et al., 2008, see Figure 1.2). The non-verbal affective voices used as stimuli in this thesis are taken from the Montreal Affective Voices (Belin et al., 2008) and are designed to represent an auditory equivalent of the affective faces by Ekman and Friesen (1976). It is important to stress that non-verbal emotional utterances are free of semantic context which might interact with identification of affective prosody. The stimuli are described in more detail in Chapter 2.

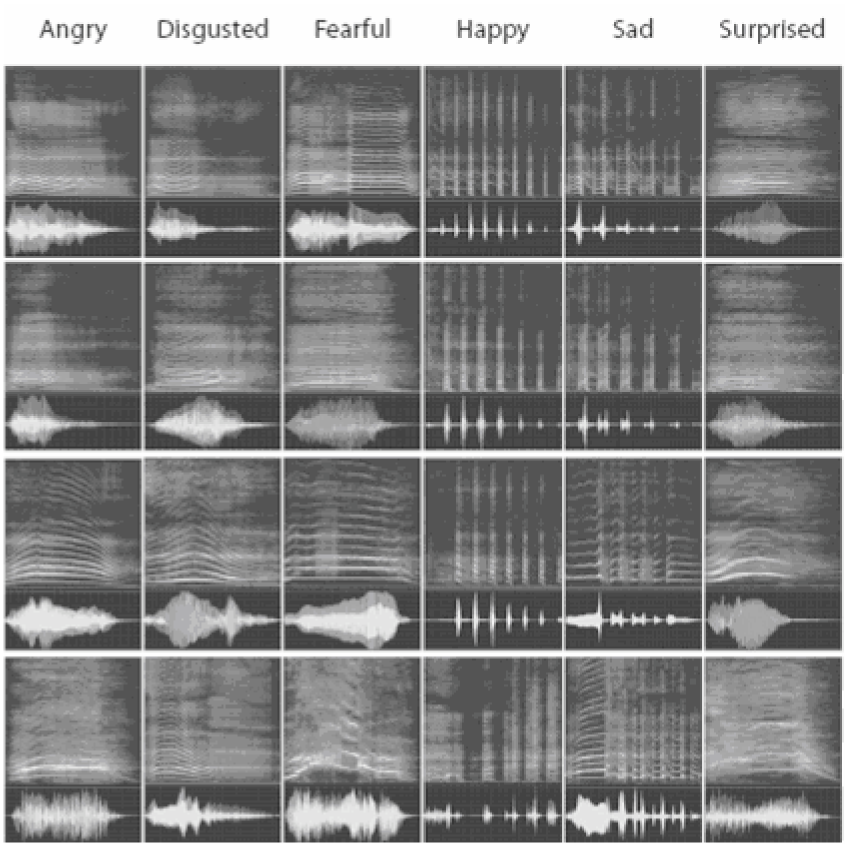

Figure 1.2. Montreal Affective Voices. Each row corresponds to one actor making vocalizations, and each column to a category of non-verbal affective burst. Adapted from Belin et al. (2008).

Emotional brain

There are numerous brain areas implicated in emotion processing from faces and voices. It has been suggested that brain regions responsible for processing emotional expressions from faces and voices are predominantly situated in the frontal and temporal brain regions (see Figure 1.3).

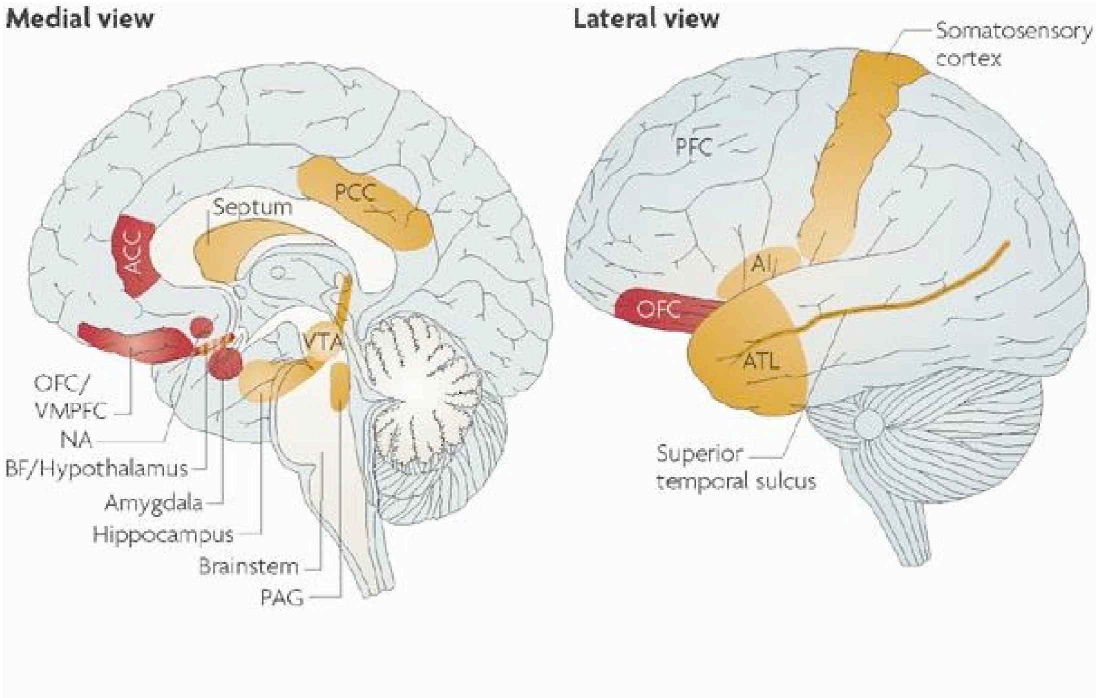

Figure 1.3. The emotional brain. Brain regions are listed here based on an informal assessment of the frequency with which they appear in the literature; regions appearing with greater frequency will be labelled 'core', and less frequent ones as 'extended'. The core emotional regions (dark red areas in figure) include, subcortically, the amygdala, the nucleus accumbens (NA) and the hypothalamus, and cortically, the orbitofrontal cortex (OFC), the anterior cingulate cortex (ACC) (especially the rostral part) and the ventromedial prefrontal cortex (VMPFC). Extended regions (brown areas) include, subcortically, the brain stem, the ventral tegmental area (VTA) (and associated mesolimbic dopamine system), the hippocampus, the periaquaeductal grey (PAG), the septum and the basal forebrain (BF) (including the nucleus basalis of Meynert); and cortically, the anterior insula (AI), the prefrontal cortex (PFC), the anterior temporal lobe (ATL), the posterior cingulate cortex (PCC), superior temporal sulcus, and somatosensory cortex. Taken from Pessoa (2008).

The role of amygdala has been consistently documented as an important brain region for processing facial emotions (Adolphs et al., 2005; Winston, O'Doherty, & Dolan, 2003), with particular involvement in the decoding of the facial expression of fear (Adolphs, Tranel, Damasio, & Damasio, 1994; Phan, Wager, Taylor, & Liberzon, 2002; Whalen et al., 2001). The cingulate cortex and the orbitofronal cortex (OFC) are believed to be active during recognition of the facial expression of anger (Blair & Cipolotti, 2000; Murphy, Nimmo-Smith, & Lawrence, 2003) whereas the decoding of disgust on faces is thought to be mediated by the insula and basal ganglia. Other negative facial emotions, such as anger and sadness seem to involve orbitofrontal and temporal brain regions when compared to happy facial expressions which are known to activate the basal ganglia (for a review see Ruffman, Henry, Livingstone, & Phillips, 2008).

Labelling emotion from voices tends to activate various brain regions placing most demands on frontal networks (Mitchell, Elliot, Barry, Cruttenden, & Woodruff, 2003, Pourtois, de Gelder, Bol, & Crommelinck, 2005). Individual emotions from vocal expressions and their relationship with brain areas are less clear. However, it was found that the OFC (Sander et al., 2005) and amygdala (Scott et al., 1997) respond to negative vocal emotions of anger and sadness. The amygdala and insula are also activated by vocal expressions of fear (Morris, Ohman, & Dolan, 1999). Of course, linking brain regions to specific emotions is problematic because none of the brain regions are ‘purely affective’ (Pessoa, 2008). It has been suggested that older adults’ poorer ability to process certain emotions might be attributed to age related changes in the brain responsible for individual emotions (e.g. Ruffman et al., 2008). This issue is addressed in Chapter 2 when reviewing the patterns of age differences in unimodal emotion identification from faces and voices (Experiments 1 and 2).

Age differences on emotion perception

Previous literature suggests that older adults perform poorer than younger adults when identifying the facial emotions anger, sadness and fear (Isaacowitz et al., 2007; Ruffman et al., 2008). There are also numerous studies reporting age related decline in the identification of vocal expressions (Mitchell, 2007; Raithel & Hielscher-Fastabend, 2004; Orbelo, Grim, Talbott & Ross, 2005). The overall patterns of findings suggest that older adults display problems with prosodic emotion recognition but it is difficult to directly address age effects on emotion recognition from voices due to the use of a wide range of vocal emotional stimuli, some which carry spoken semantic context and some which involve neutral speech prosody. Nevertheless, there is a consensus that older adults tend to perform poorer than younger adults in the identification of negative emotions from faces and voices (Ruffman et al., 2008).

One of the hypotheses accounting for older adults' poor performance on negative emotion identification is that older adults, through a lifetime of experience in monitoring and regulating emotions, have developed a bias to attend away from negative information and instead focus on the positive (see Mather & Carstensen, 2003; Carstensen & Mikels, 2005; Carstensen, Fung & Charles, 2003). The aging literature looking at emotion perception consistently reports older adults' difficulties in recognizing negative emotions, in particular fear, sadness and anger (Issacowitz et al., 2007; Ruffman et al., 2008). This phenomenon might be explained by the Socioemotional Selectivity Theory (SST; Carstensen et al., 2003) and is termed as age related 'positivity bias' where older adults seem to pay more attention to positive emotions and events than negative ones. It is believed that this bias develops as an adaptive strategy to improve older adults' wellbeing and ability to cope with emotional distress. However, older adults' difficulty in recognizing negative emotions might be also related to age differences in gaze perception. It has been documented that older adults look differently at the various facial features important for decoding emotions. For instance, studies using eye-tracking found that older adults tend to look more at the mouth and less at the eye region when compared with younger adults (Sullivan, Ruffman, & Hutton, 2007). This issue of processing emotional information is related to differences in gaze behaviour in older and younger adults and will be addressed further in Chapter 4.

There are also other possible explanations for emotion perception difficulties in older adults, such as cognitive changes with age. For instance, it has been reported that age-related decline in IQ could affect the way we process emotion (Salthouse, 2000). In the study of Salthouse (1993), it was found that increasing age affects performance on abstract reasoning tests such as Raven's Progressive Matrices. However, age effects were not present on tests assessing acquired knowledge. In other words, aging affects the type of intelligence responsible for the processing of novel or complex information, i.e. fluid abilities. However, older adults perform as well as younger adults on crystallized intelligence tests. Nevertheless people with lower fluid IQ tend to perform less well on tasks assessing emotion recognition (e.g., Moore, 2001). There is also evidence showing that increased demand on working memory or executive functioning compromises older adult's ability to perform on social cognition tasks (e.g. Orgeta & Phillips, 2008; Salthouse, 1994, 2000). Patient's data also suggest that social cognition tasks are related to executive function measures (e.g. Channon & Crawford, 2000; Mah, Arnold, & Grafman, 2004; Phillips, Tunstall, & Channon, 2007) and that executive functions contribute to the development of socio-cognitive skills (Carlson and Moses, 2001). Hence, one of the aims of this thesis is to explore whether age-related declines in emotion recognition might reflect general cognitive deficits. This issue is explored in more detail in Chapter 3

Principles of multisensory integration

Research investigating the relationship between age-related changes in social perception and multisensory integration is limited. Previous research has focused on age-related differences on emotion perception in a single modality. Indeed, most of the aging studies have considered facial expression recognition or emotional prosody separately and the present knowledge of the interaction between multisensory decoding of emotions presented to multiple modalities is limited. Therefore, the major aim of this PhD thesis is to investigate if older adults can compensate for their difficulties in processing emotions in a single modality through multisensory integration.

Generally, multisensory integration is the area of study investigating how information from multiple sensory modalities is integrated into our nervous system. The capacity of our brain to integrate different sensory cues arising from a common source provides us with a coherent percept of the world and is central to adaptive behaviour. On the neural level, multisensory interactions resemble behavioural consequences of multisensory integration. Hence, multisensory integration is also reflected by '*neural processes involved in synthesizing information from cross-modal stimuli (...) At the level of the single neuron, multisensory integration is defined operationally as: a statistically significant difference between the number of impulses evoked by a cross-modal combination of stimuli and the number evoked by the most effective of these stimuli individually*' (Stein & Stanford, 2008, p.255). To study multisensory integration, researchers use different types of cross modal stimuli, (e.g. verbalisation of a colour word and a colour circle presented concurrently), and compare the performance of participants on cross-modal conditions relative to only one modality (only the colour word verbalisation or only the colour circle). It has been found that cross-modal stimuli can enhance or inhibit behaviour. For example, in everyday conversation, seeing speakers' facial movements at the same time as hearing the voice improves speech understanding (Sumby & Pollock, 1954). This example illustrates when cross-modal information is congruent (the same), it results in behavioural and neural enhancement increasing the likelihood for event detection (see Figure 1.4).

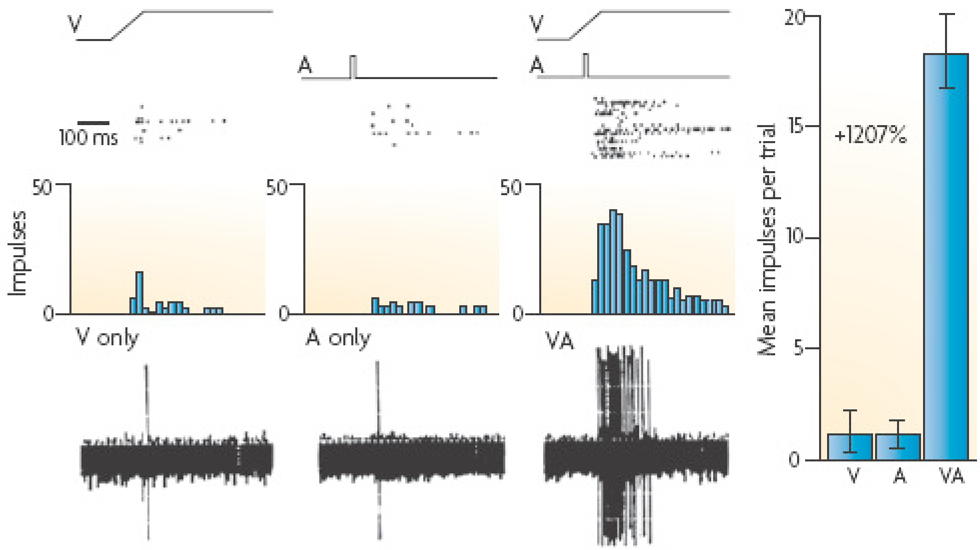

Figure 1.4. Multisensory enhancement in a single superior colliculus neuron. Depiction of visual (V), auditory (A) and combined (VA) stimuli, impulse rasters (in which each dot represents a single neural impulse and each row represents a single trial), peristimulus time histograms (in which the impulses are summed across trials at each moment of time and binned), single trace oscillograms and a bar plot depicting the response of a superior colliculus (SC) neuron to the stimulation. Note that the multisensory response greatly exceeds the response to the either stimulus alone, thereby meeting the criterion for multisensory integration (that is, response enhancement). Figure taken from Meredith and Stein (1986).

In contrast, when cross-modal stimuli are incongruent, it causes our neural network to be less responsive resulting in poorer detection of the event, known as cross-modal interference or inhibition (for a review, see Stein & Meredith, 1993). For instance, when conflicting information is presented across different sensory modalities e.g. when watching a person saying '*one speech syllable while listening to another typically result in perception of a third sound that represents a combination of what is seen and heard which is a combination what is seen and heard'* (Spence & Driver, 2004 p.1; see also McGurk & MacDonald, 1976) producing cross-modal identity conflict. Of course, in order to observe the behavioural effects of multisensory integration, cross-modal stimuli have to correspond in time and space and share similar content-related features, such as those involved in audio-visual emotion recognition (Meredith & Stein, 1986). Moreover, it has also been suggested that there are specific multisensory brain regions dedicated to processing signals from faces and voices. It was consistently reported in studies of primates and the human brain that in particular the superior temporal sulcus (STS) seems to play a major role in the integration of face-voice signals (Calvert, Campbell, & Brammer, 2000; Ghazanfar, Maier, Hoffman, & Logothetis, 2005; see also review Stein & Stanford, 2008).

Multisensory integration in damaged brains

Indeed, one of the functions of our brain is to successfully integrate cross-modal stimuli from different modalities and integrative processes might malfunction in a damaged brain. Therefore, the other matter addressed in this thesis is to investigate whether multisensory integration of relevant sensory information in order to control social behaviour is one of the underlying deficits in stroke patients who report changes in their social and emotional processing (Chapter 5). Previous studies of stroke patients have only examined the prevalence of changes in behaviour and personality rather than their underlying deficits (Aybek et al., 2005; Stone et al., 2004). An understanding of why these changes occur not only enhances our knowledge of these phenomena but is also a first step in the process of designing interventions to address them, and in turn adds to our understanding of how these functions are organised in the healthy brain. Similar studies investigating behavioural changes following traumatic brain injury (TBI) and particular types of dementia have suggested that patients are impaired in their ability to understand the mental states of others and identify emotions (McDonald & Flanagan, 2004), despite their basic knowledge of social rules remaining intact (e.g. Lough et al., 2006; Saver & Damasio, 1991). However, the examination of multisensory integration in relation to impairments in social processing is a novel approach in the social neuroscience literature.

Overview of the thesis

The aim of this PhD is to assess whether older adults can benefit from information presented across multiple channels of information in emotion perception tasks (Chapter 2). The next interest is to determine whether performance on cross-modal tasks related to emotions might be specific to social interaction or simply cognitive control in general (Chapter 3). It has been previously suggested that age-related changes in eye-gaze perception are related to emotion perception difficulties. Therefore, the age differences in the processing of relevant and irrelevant visual and auditory social information and their association to gaze behaviour is also a topic of this thesis (Chapter 4).

Another point is to investigate whether impairments in social cognition in stroke patients might be linked to specific deficits in the integration of auditory and visual emotional and social cues (Chapter 5). Moreover, the final goal of this thesis is to reconsider age effects on the perception of social situations in naturalistic settings where people are presented with real voices and real faces and derive meaning from different e.g. paralinguistic and contextual cues (Chapter 6).

In summary, using multidisciplinary approaches, this PhD thesis is designed to understand the integration of visual and auditory cues in social situations and how this is associated with other factors important in social situations. A series of experiments will investigate how the healthy brain combines what it hears and sees and examines whether there are affects of healthy adult aging on the multisensory integration of social information. Moreover, the project will investigate whether impairments in social cognition in neurological patients are related to specific deficits in the early processing of emotional and social information or the integration of auditory and visual emotional and social cues. Understanding the close link between the processing of relevant and irrelevant visual and auditory information in social interactions and how multisensory integration of that information relates to performance on other measures of social cognition may shed more light on what are the underlying deficits in emotional processing in healthy adult aging and stroke patients.

Chapter 2: The Effects of Healthy Adult Aging on Unimodal and Cross Modal Emotion Perception

Introduction

In everyday situations our brain integrates information from multiple sensory signals to enhance perception and guide behaviour. When information from multiple sensory signals is congruent this facilitates behaviour, resulting in faster response times and increased accuracy (Calvert, Spence, & Stein, 2004; Forster, Cavina-Pratesi, Aglioti, & Berlucchi, 2002; Hughes, Reuter-Lorenz, Nozawa, & Fendrich, 1994). However, the need to integrate incongruent from different sensory modalities can impair the ability to process incongurent information (Calvert et al., 2004; Meredith & Stein, 1986, 1996; Stein & Meredith, 1993). So far, little is known about age effects in processing congruent and incongruent audio-visual information. It has been suggested that older adults benefit more than younger adults from semantically congruent multisensory information (Laurienti, Burdette, Maldjian, & Wallace, 2006). The current study investigates whether this benefit for older adults from multiple channels of information extends to emotionally salient cues.

Successful social interaction in everyday situations requires individuals to successfully orchestrate information received through multi-sensory channels such as emotional visual cues from faces and gestures and emotional prosody from voices (Russell, Bachorowski, & Fernandez-Dols, 2003). Relatively few studies have investigated integration of emotional cues presented in the audio and visual channels (see; Campanella, & Belin, 2007; Collignon et al., 2008). Nevertheless, it has been postulated that congruence between facial emotion and voice prosody speeds and increases accuracy of reactions to stimuli (e.g. de Gelder & Vroomen, 2000; Ethofer, Pourtois, & Wildgruber, 2006). For instance, congruent cross-modal presentation of a fearful voice facilitates recognition of a fearful facial expression (de Gelder, Dolan, & Morris, 2001). However, knowledge of multisensory processing of social stimuli in old age is much more limited.

Most aging studies have focused on the processing of emotional cues only in the visual modality (Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006) or in the auditory modality (Allen & Brosgole, 1993). Key results indicate that older adults are less able to distinguish different negative emotions via unimodal visual and auditory channels compared to younger adults (Brosgole & Weisman, 1995; MacPherson, Phillips, & Della Sala, 2006; Phillips, MacLean, & Allen, 2002; Ruffman et al., 2008; Wong, Cronin-Golomb, & Neargarder, 2005), which are explored further in Experiment 1 and 2. In particular, older adults show difficulty in identifying anger, sadness and fear from faces, as well as identifying prosodic expressions of anger and sadness (for a review see Ruffman et al., 2008). One of the hypotheses for older adults' poor performance on negative emotion identification is that older adults, through a lifetime of experience in monitoring and regulating emotions, have developed a bias to attend away from negative information and instead focus on the positive (see Mather & Carstensen, 2003; Carstensen & Mikels, 2005; Carstensen et al., 2003). There are also other possible explanations for the pattern of emotion perception difficulties of older adults, such as cognitive and neuropsychological changes (Ruffman et al., 2008).

The main focus of this chapter is on the effects of aging on cross-modal emotion perception. But in order to investigate if there are differential age effects on unimodal and cross-modal emotion processing we also look at age related differences in identification of emotions only from faces and only from voices. This will also allow comparison of this study with other studies of age differences in emotion perception in the literature.

Aims of Experiment 1 and 2

It is predicted that on both visual and auditory unimodal emotion identification tasks older adults would perform more poorly than younger adults when the emotions are negative in valence, in line with the aging literature described above.

Experiment 1: Unimodal Facial Emotion Identification

Effects of age on emotion recognition from faces

Faces encode information such as identity, age, and gender, as well as emotional expression. Facial emotion plays a core role in social interaction (Ekman, 1992). Failure to recognize emotions portrayed in faces, is often accompanied by problems understanding the intentions of other people, their feelings, and problems responding in an appropriate manner to their current emotional state. It has been reported that older adults perform more poorly than younger adults in recognition of certain emotions from faces. In particular, older adults display problems with the recognition of negative emotions from faces such as fear, sadness and anger (for review, see Ruffman et al., 2008). These findings are supported by evidence from previous emotion identification studies in the literature such as MacPherson et al. (2006); Phillips et al. (2002) and Ruffman et al. (2008) who also found that older adults performed more poorly than younger adults on negative emotion recognition.

Age related brain changes in processing emotions from faces

One of the factors contributing to the poorer performance of older adults on negative emotion identification might be age related changes in the brain. There are number of brain areas important for processing of emotional expression from faces such as the orbitofrontal cortex (OFC), which is believed to be particularly important for decoding of anger (Blair & Cipolotti, 2000; Blair, Morris, Firth, Perrett, & Dolan, 1999). Given the evidence that the OFC is one of the brain areas that deteriorates rapidly (Allen, Bruss, Brown, & Damasio, 2005a; Phillips & Henry, 2005), it may contribute to older adults' difficulty in anger recognition (e.g. Ruffman et al., 2008).

As the amygdala is mainly responsible for decoding of fear (e.g., Adolphs et al., 1994; Adolphs, Tranel, Damasio, & Damasio, 1995; Posamentier & Abdi, 2003, Phan et al., 2002), older adults' poorer performance on identification of fear (but also to some extent anger and sadness, (e.g. MacPherson et al., 2006) might be caused by age related reduction in amygdala volume (e.g. Allen et al., 2005a; Allen, Bruss, Brown, & Damasio, 2005b). Older adults' ability to correctly identify disgust which is processed by the basal ganglia and insula (Phan et al., 2002) remains unclear with some studies suggesting age improvements in identification of this emotion (e.g. Ruffman et al., 2008).

Facial stimuli

This experiment assesses age differences in facial affect recognition using a standardized series of Ekman and Friesen (1976) stimuli, which have been adopted in numerous studies. The series depicts six basic emotions (sadness, disgust, fear, anger, surprise & happiness) portrayed on black and white photographs of Caucasian models. As some studies reported cultural differences on emotion identification in terms of emotional intensity ratings and accuracy (e.g. Russell, 1994; Ortony & Turner, 1990; Matsumoto, 1989, 1990), only British-Caucasian individuals were recruited in the current study.

Method

Participants in Experiments 1-3

Fifty healthy volunteers were recruited through the volunteer database held at University of Edinburgh: 25 younger adults (9 men, 16 women) aged between 18-40 with a mean age of 22.64 years (SD = 5.86) and 25 older adults (15 men, 10 women) aged between 60-79 with a mean age of 66.96 years (SD = 6.10). All participants were right handed. Verbal ability was assessed using the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) was used to assess speed of processing. Older and younger adults did not significantly differ in years of education, t (48) = -.37, p= .71, or verbal ability, t (48) = -1.66, p = .10. However, in terms of speed of processing older adults were significantly slower than younger adults, t (48) = 5.57, p <.001 (see also Table 2.1).The two groups did not differ significantly with regard to gender, χ^2 (1, 50) =2.88, p=.09. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the Wechsler Adult Intelligence Scale-III UK selection criterion (Wechsler, 1997).

Table 2.1. Means and standard deviations for the participant characteristics

	Younger Adults (n = 25)		Older Adults (n = 25)	
	M	*SD*	*M*	*SD*
Years of full-time education	15.08	2.25	15.40	3.67
WTAR	111.24	5.31	113.88	5.94
DSST	67.76	10.91	51.20	10.10

Note: WTAR = Wechsler Test of Adult Reading; DSST = Digit Symbol Substitution Test

Materials

Neuropsychological Assessment in Experiments 1-3

There are number of factors which can act as potential mediators of age related decline in the ability to decode emotional expression from faces and from voices, such as hearing and vision impairment and decline in IQ and cognitive functioning. In order to ensure that performance of participants is not compromised by these factors our participants were assessed on some neuropsychological tests described below.

The Wechsler Test of Adult Reading (WTAR; Wechsler, 2001). Premorbid cognitive function was estimated using the WTAR. The WTAR consists of 50 irregular words with irregular grapheme-to-phoneme translation and does not require knowledge of a word meaning nor textual comprehension. The use of irregular words assesses participants' current ability to use standard pronunciation rules and maximises assessment of the previous learning of the word (Grober & Sliwinski, 1991). The test was administered using the standard published test and materials. Participants were presented with a single A4 sheet containing 50 words, and were asked to read aloud the list of words at their own pace. Participants' responses were recorded and then scored by the experimenter. An estimate of premorbid IQ was derived by converting raw scores to estimated IQ scores using the WTAR-Demographics-Predicted standardised conversion table.

Digit Symbol Substitution was taken from Wechsler Adult Intelligence Test (WAIS-III; Wechsler, 1997). The test assesses perceptual and graphomotor speed of processing. The digit symbol substitution task contains rows of blank squares with assigned numbers which range from 1 to 9. Each number is paired with a corresponding nonsense symbol. The task is to fill in order as many empty squares as possible with the corresponding symbols within 90 seconds of time.

The score of this test represents the number of blank squares filled within the time limit of 90 seconds. Participants were awarded a point for each correctly filled square. Scaled score equivalents of raw scores for Digit Symbol Substitution (DSS) are presented in Table 2.2.

Table 2.2 Scaled score equivalents of raw scores for Digit Symbol Substitution (DSS) with various age groups.

Scaled Score	DSS Ages 18-19	DSS Ages 20-24	DSS Ages 25-34	DSS Ages 35-44	DSS Ages 55-64	DSS Ages 65-69	DSS Ages 70-74
19	93	93	93	92-93	88-93	78-93	72-93
18	90-92	91-92	91-92	90-91	82-87	72-77	65-71
17	87-89	89-90	88-90	87-89	76-81	66-71	59-64
16	83-86	85-88	83-87	82-86	71-75	62-65	53-58
15	78-82	81-84	77-82	74-81	67-70	57-61	49-52
14	74-77	77-80	73-76	69-73	61-66	52-56	46-48
13	70-73	73-76	68-72	66-68	56-60	48-51	43-45
12	66-69	68-72	65-67	62-65	51-55	44-47	39-42
11	61-65	64-67	60-64	57-61	46-50	40-43	34-38
10	57-60	59-63	57-59	51-56	42-45	36-39	29-33
9	52-56	54-58	52-56	47-50	35-41	32-35	25-28
8	47-51	49-53	48-51	43-46	30-34	27-31	21-24
7	43-46	44-48	44-47	36-42	23-29	21-26	18-20
6	37-42	39-43	36-43	30-35	18-22	15-20	14-17
5	31-36	31-38	29-35	22-29	14-17	10-14	10-13
4	24-30	26-30	22-28	16-21	10-13	7-9	7-9
3	16-23	18-25	15-21	11-15	7-9	5-6	4-6
2	7-15	8-17	8-14	5-10	4-6	3-4	2-3
1	-	0-7	-	0-4	0-3	0-2	0-1

Screening Tests

To check for cognitive and perceptual problems in older adults, the following screening tests were administered to the older participants in all the experiments included in this PhD thesis: Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton, Sivan, Hamsher, Varney, & Spreen, 1983) & Florida Affective Battery: Subtest 6 & 7 (FAB; Bowers, Blonder, & Heilman, 1991). In this and subsequent experiments there were no participants who needed to be excluded based on the criteria used in these tests (see Appendix 1 for screening test results).

Cognitive Screening

Mini Mental State Examination (MMSE; Folstein et al., 1975). MMSE was used as a screener to ensure that our older participants had normal cognitive functioning. The MMSE assesses orientation to time and place, attention and concentration, language, constructional ability, and immediate and delayed recall (Spreen & Strauss, 1998, p.65). All participants recruited for the study scored above the recommended normal cut-off of 26 out of a possible 30 (Lemsky, Smith, Malec, & Ivnik, 1996).

Perceptual Processing

Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983). This test assesses the capacity to discriminate and identify photographs of familiar and unfamiliar faces. It was found that individuals who are not able to recognize familiar faces (known as facial agnosia) often suffer with a visual field deficit, achromatopsia, spatial disorientation, or visuo-constructive disorder (Benton et al., 1983). The purpose of this test was to control for problems with visual processing in our sample. In the current study a Short Form of Benton Facial Recognition Test (Benton et al., 1983) was used which consists of 27 items and is composed of three parts. In the first part of the test participants had to match identical front view photographs with a total of six possible responses. In the second part participants had to match a single front view photograph with 3 other faces in a display of six faces which were presented with six three quarter views giving a total of 12 responses. Finally, in the third part participants were presented with a single front view photograph taken under full lighting conditions and asked to match it with three out of six other photographs of faces which were taken under different lighting conditions, given a total of 9 responses. The correct responses and errors were recorded on the record sheet and converted from the Short Form into age and education corrected Long Form scores.

Our older adults performed within the average or above average (> 43) range on the Benton Facial Recognition Test, suggesting any differences in performance between our age groups are not due to an inability to process faces. Facial recognition normative standards with scores corrected for age and years of education, are as follow: 53-54 superior, 50-52-superior 47-49 high average, 43-46 average, 41-41 low average, 39-40 borderline, 37-38 defective, less than 37 severely defective.

Florida Affective Battery (FAB; Bowers et al., 1991). This test is sensitive to problems in the perception and understanding of nonverbal communicative signals of emotion (Bowers et al., 1991). In the current study, only two subtests were used where participants were asked to discriminate if spoken emotional or nonemotional tones were the same or different.

Nonemotional prosody discrimination (Subtest 6). Participants were presented with 16 pairs of spoken sentences through headphones. The sentences were spoken in either an interrogative (e.g.' *fish jump out of water?*') or declarative tone of voice (e.g.*' fish jump out of water'*). On half the trials, the two sentences were questions. For the remaining trials, the two sentences were different i.e. one will be a statement and one a question. Participants had to judge whether the sentence pairs were the same or different in terms of their tone of voice. The normative score for participants of 60 years of age was 96.3%, and for participants with an age range of 61-70 years, the score was 95.8 %. All participants scored above the cut-offs for all the screening tests described above

Emotional prosody discrimination (Subtest 7). Participants were presented with 20 pairs of spoken sentences through headphones. The sentences were spoken in either the same or a different emotional tone of voice. Participants had to judge whether the sentence pairs were the same or different in terms of their emotional tone of voice. The normative scores for discrimination of emotional prosody for adults of 60 years of age were 98.8 %, and for participants with an age range of 61-70 years the score was 98.4 %. In this test participants scored within the normative range.

Experimental Task

Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002).

The ability to recognise emotional expressions from faces was tested using the *Facial Expressions of Emotion: Stimuli and Test (FEEST;* Young et al., 2002). Sixty black and white photographs of faces displaying one of the six basic emotions (happiness, surprise, fear, sadness, disgust, anger) were shown, one at a time, in the middle of a computer screen. Participants were instructed to choose which of the six labels best described the emotion displayed on each face by choosing one of the verbal labels (see Figure 2.1). Photographs were presented in a pseudorandom order, and 10 examples of each emotion were displayed. The faces were shown for a period of 5 seconds each, but participants could take as long as they wished to decide on the emotion and no feedback was given about the accuracy of a participant’s choices. The task started with 6 practice trials. The dependent variable was percentage accuracy for each emotion (see Appendix 2 for test instructions).

Happy Surprise Fear Sadness Disgust Anger

Figure 2.1. Example stimulus in the emotion recognition task

Procedure

All participants in Experiments 1-3 performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the Digit Symbol Substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing. In addition, older adults performed the screening tests described in Experiment 1 to rule out cognitive and perceptual problems: the Mini Mental State Examination (MMSE; Folstein et al., 1975), the Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983) and the Florida Affective Battery: Subtests 6 & 7 (FAB; Bowers et al., 1991).

Then all participants performed the three tasks, facial emotion recognition (Experiment 1), prosodic emotion recognition (Experiment 2) and the cross-modal emotion matching task (Experiment 3). The order of these tasks was counterbalanced across participants. In each of the tasks the sound level was adjusted to be comfortable for each participant and participants were seated approximately 50 cm from the visual display.

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. They were reimbursed for any expenses incurred for taking part. Informed consent was obtained for all research volunteers according to the Declaration of Helsinki and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee at the University of Edinburgh, and the Psychology Ethics Committee at the University of Aberdeen.

Results

A mixed 2 (age: young and old) x 6 (emotions: anger, fear, disgust, sadness, happiness and surprise) ANOVA was conducted on the percentage of correct identifications of facial expressions of emotion; see Table 2.3 for descriptive information. There was a main effect of emotion, F (5, 240) = 18.03, $p < .001$, η_p^2 =.27. Pair wise comparisons with Bonferroni adjustment revealed that happiness was identified significantly better than all other emotions (anger, $p < .001$); fear, ($p <$ .001); sadness ($p < .001$); disgust ($p< .001$) and surprise ($p< .001$). There was also a main effect of age such that older adults performed significantly more poorly than younger adults ,F (1, 48) = 29.25, $p< .001$, $\eta_p^2 = .38$. The interaction between age and emotion approached significance, F (5, 240) = 2.10, $p = .07$, $\eta_p^2 = .04$. Further analysis was therefore conducted using independent-samples t-tests to explore age differences on each emotion. The results suggest that younger adults performed significantly better than older adults on identification of anger, t (48) = 3.57, $p <$. 001; sadness t (48) = 3.27; $p = .002$; surprise, t (48) = 2.40, $p = .02$ and fear, t (48) = 2.19; $p = .03$, but not happiness, t (48) = 1.50; $p = .14$ and disgust, t (48) = .41; $p =$ .68.

Table 2.3. Mean percentage accuracy and standard deviations for younger and older adults performing the unimodal facial emotion identification.

	Younger Adults (n = 25)		Older Adults (n = 25)	
	M	*SD*	*M*	*SD*
Facial Emotion Recognition				
Happiness	99.20	2.77	96.80	7.48
Surprise	88.80	9.71	80.80	13.51
Fear	79.60	16.70	68.80	18.10
Sadness	88.40	13.44	74.80	15.84
Disgust	84.80	14.18	83.20	13.45
Anger	86.00	10.40	71.60	17.24

Discussion

The results of this experiment indicate that older adults performed less well than younger adults on negative emotion recognition from faces on anger, sadness and fear but not disgust. In the recent review by Isaacowitz et al. (2007), it was reported that anger, sadness and fear are among the worse recognized emotions by older adults across all aging studies. The lack of age effects on the recognition of disgust in the current experiment is compatible with evidence from other aging studies reporting no age effect on the recognition of disgust (see Ruffman et al., 2008), or in some instances even better ability to recognize disgust by older adults (Isaacowitz et al., 2007). In this study older adults also identified surprise less well than did older adults. Although surprise is often perceived as a positive or neutral emotion, it could also have a negative element (Ruffman et al., 2008).

Socioemotional Selectivity Theory (SST; Carstensen et al., 2003) proposes that age differences in the perception of negative emotions are caused by a bias where older adults are more motivated to attend to positive facial expressions, such as happiness and ignore negative facial expressions (Carstensen, Isaacowitz, & Charles, 1999; Mather & Cartensen, 2003). Ruffman et al. (2008) argue that '*if positivity bias leads to emotion recognition errors, older adults should be better in labelling positive emotions compared to negative emotions, but results indicated that older adults were frequently worse when labelling expressions of happiness*' (p.871). Although the current results show that younger adults' accuracy was slightly higher than older adults in identifying happiness, the effect sizes were too small to reach a significant difference. Also the often reported ceiling effects in the recognition of happiness makes the results difficult to interpret.

Therefore, the results from Experiment 1 suggests that older adults perform poorer than younger on identification of negative emotion from faces. The next experiment looks at age-related differences in emotion recognition from voices.

Experiment 2: Unimodal Prosodic Emotion Identification

Age effects on emotion identification from voices

Numerous studies have also reported that older adults' process emotions presented via auditory channels differently compared to younger adults (e.g. Brosgole & Weisman, 1995; Isaacowitz et al., 2007; Wong et al., 2005). Successful social communication requires decoding of emotional states of others. Problems with decoding emotion from voices, as well as from faces, may impair the ability to behave in a socially accepted way and interpret emotional states and intention of other people (Trauner, Ballantyne, Friedland, & Chase, 1996).There are a number of studies that have looked at whether there is an age related decline in the identification of vocal expression (Mitchell, 2007; Raithel & Hielscher-Fastabend, 2004; Orbelo, Grim, Talbott, & Ross, 2005).

Although overall patterns suggest that older adults display problems with prosodic emotion recognition, only a few studies have looked at the individual emotions in separation (Wong et al., 2005; Brosgole and Weisman, 1995). Wong et al. (2005) postulated that older adults performed worse on identification of auditory expressions of sadness and happiness, but recognition of auditory expressions of angry, fearful, disgusted and surprised was not compromised by age. In contrast, Brosgole and Weisman (1995) showed that there is an age related reduction in the emotion recognition of anger, sadness and happiness. It should be noted that the studies of Brosgole and Weisman (1995) and Wong et al. (2005) investigated age related changes in emotion using tone (prosody) as opposed to semantic content. Emotional information can be tested in the auditory modality in different ways. For instance, auditory stimuli can contain words or sentences, or simply be composed of voice prosody where emotions are distinguished only from the tone of voice. In some cases voice prosody is added to semantic meaning and can either reinforce or contradict semantic meaning (Dupuis & Pichora-Fuller, 2010). The study of Isaacowitz et al. (2007), which used sentences containing a description of the situation that had to be read by participants, found that older adults performed significantly more poorly than younger adults on the descriptions of situations where anger, disgust, surprise, and happiness were involved. However, a recent study by Dupuis and Pichora-Fuller (2010) suggests that *'age–related differences in* *perceiving emotions were eliminated when listeners repeated the sentences before responding'* (p.16).

Affective prosodic stimuli

One of the factors contributing to inconsistencies in emotion recognition from voices might be related to the fact that most of the auditory affective stimuli previously used carry linguistic content (Monrad-Krohn, 1963) which might interact with identification of affective prosody. For instance, Mitchell (2007) argues that concurrently presented semantic information with conflicting voice prosody can reduce a participant's performance. In the current study our prosodic stimuli are composed of non verbal affective bursts which are short interjections of the vowel 'a' (Belin et al., 2008). Affective bursts are "*short, emotional nonspeech expressions, comprising both clear nonspeech sounds (e.g., laughter) and interjections with a phonemic structure (e.g. 'Wow!'), but excluding 'verbal' interjections that can occur as a different part of speech (like 'Heaven!', 'No!', etc)*" (Schröder, 2003, p.103), which are less likely to be subject to interference between semantic content and prosody judgments.

Age related brain changes in processing emotions from voices

It was found that there are numerous brain areas involved in the processing of emotional auditory and vocal stimuli (Shirmer & Kotz, 2006). The brain areas especially important for labeling of voice prosody are located in the frontal lobes, i.e. orbitofrontal cortex (OFC; Van Hoesen, Parvizi, & Chu, 2000) and inferior frontal gyrus (Buchanan et al., 2000; George et al., 1996; Wildrguber et al., 2005). Although it is believed that OFC is involved in labeling of all kinds of prosodic expression (Buchanan et al., 2000; Wildgruber et al., 2005), some studies suggests that the OFC is particularly activated when labeling sad and angry vocal expressions (Sander et al., 2005; Hornak et al., 2003). Given the evidence of age related brain changes in frontal and temporal regions (Raz et al., 2005), it is plausible to hypothesize that age related difficulties in the identification of vocal expressions may be driven by age related changes in the brain. The current experiment investigates if older adults would perform more poorly than younger adults on negative emotion identification from voice prosody.

Method

Participants

The same 50 participants described in Experiment 1 participated in this experiment.

Materials & Procedure

Auditory affective stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA) and were presented through headphones. The prosodic emotional stimuli were taken from the *Montreal Affective Voices* (Belin et al., 2008) which take the form of short non-linguistic interjections of the vowel /a/. The set contained a series of nonverbal affective emotions (anger, disgust, fear, happiness, sadness, and surprise). In the current paradigm the prosodic stimuli were presented for no longer than 450 ms. Four female voices and four male voices were used, all portraying an example of each emotion. Therefore, each vocal emotion (anger, disgust, fear, happiness, sadness and surprise) was presented 8 times giving a total of 48 trials. Prior to performing the task, participants performed 6 practice trials. For each trial, participants decided whether the interjection was most like happiness, sadness, surprise, fear, disgust or anger. No feedback was given. Participants could take as long as they wished to decide on the emotion. The stimuli were presented in random order. The dependent variable was percentage accuracy (see Appendix 3 for test instructions).

Results

Descriptive information for this task is also shown in Table 2.4. A 2 (age: young and old) x 6 (emotions: anger, fear, disgust, sadness, happiness and surprise) ANOVA was conducted on the percentage of correct responses. There was a main effect of age, F (1, 48) = 33.8, $p< .001$, $\eta_p^2 = .41$ and further analysis showed that older adults performed significantly more poorly than younger adults on negative prosodic emotion identification. There was also a main effect of emotion F (5, 240) = 36.09, $p < .001$, $\eta_p^2 = .43$. The results of pair wise comparisons with Bonferroni correction suggest that the vocal emotion of happiness was significantly easier to identify than anger ($p < .001$); fear ($p < .001$); disgust ($p < .001$), and surprise ($p < .001$). Among the negative prosodic emotions, anger was significantly more difficult to recognize than sadness ($p < .001$); and disgust (p < .001). The interaction between group and emotion was also significant, F (5, 240) = 7.84, $p < .001$, $\eta_p^2 = .14$. Independent sample t-tests indicated that older adults performed more poorly when recognising negative emotions from voice prosody than younger adults: anger, t (48) = 5.47, $p < .001$; fear, t (48) = 4.09, $p < .001$; disgust, t (48) = 4.88, $p < .001$, and sadness t (48) = 2.48, $p <.02$, but there were no age differences for happiness, t (48) = -.30; $p = .77$ and surprise, t (48) = -.71; $p = .48$.

Table 2.4. Mean percentage accuracy and standard deviations for younger and older adults performing prosodic emotion identification task

	Younger Adults (n = 25)		Older Adults (n = 25)	
	M	*SD*	*M*	*SD*
Prosodic Emotion Recognition				
Happiness	93.12	11.95	94.08	10.80
Surprise	58.76	21.86	62.72	17.24
Fear	84.64	13.63	63.76	21.59
Sadness	96.08	9.22	84.48	21.48
Disgust	90.08	11.39	75.16	10.21
Anger	78.68	16.65	49.76	20.53

Discussion

The results from both unimodal identification tasks supported previous results (e.g. Ruffman et al., 2008) suggesting that older adults might find identifying negative emotions more challenging than younger adults. For visual information, older adults performed more poorly than younger adults in identifying emotions of fear, sadness, surprise and anger from faces, similar to evidence from previous emotion identification studies (MacPherson et al., 2006; Phillips et al., 2002; Ruffman et al., 2008). Younger and older participants were also asked to label prosodic expressions. There are number of studies that aimed to establish whether there is an age-related decline in the identification of vocal expression (Mitchell, 2007; Raithel, & Hielscher-Fastabend, 2004; Orbelo et al., 2005) but only a few studies have looked at the emotions separately (Wong et al., 2005; Brosgole & Weisman, 1995). Wong et al. (2005) found that older adults performed worse than younger adults on the identification of auditory expressions of sadness and happiness, but not auditory expressions of anger, fear, disgust and surprise. In contrast, Brosgole and Weisman (1995) found an age-related reduction in the recognition of anger, sadness and happiness. The results from Experiment 2 indicate that older adults show difficulty in identifying negative emotions of fear, anger, sadness and disgust. This diverse pattern of findings across aging studies in voice prosody might be due to the fact that researchers use different prosodic stimuli, some of which carry linguistic content which might influence emotion recognition. Therefore, an important factor to consider in future research includes the different ways in which auditory emotions can be portrayed. As highlighted above, the results from aging studies on auditory emotion perception are not very consistent, and it would be useful to have a clearer comparison of age differences in identifying emotions from spoken semantic context, speech prosody (where content is neutral) and non-verbal emotional utterances.

The current study cannot directly test for a positivity bias in age differences in processing emotional information (Carstensen & Mikels, 2005) because this study used the six basic emotions common to most studies which only include two possible positive emotions. Surprise is often considered as a positive emotion but it can also act as a negative emotion if someone is surprised in an unpleasant manner (Ruffman, et al., 2008) and only happiness can be treated as non ambiguous positive emotion,.

In order to look at age-related positivity biases in relation to emotion perception, it would be necessary to use different types of emotional stimuli rather than the six basic emotions which are used in the majority of studies (for example varying types of smile, see Slessor, Miles, Bull, & Phillips, 2010). Future research within the area should address the effects of type of emotion on cross-modal perception with relation to age positivity bias proposed by Carstensen and Mikels (2005). This would require the development of new tasks to assess distinctions between different positive emotions, or methods of assessing attention to positive and negative information rather than reliance on accuracy of matching and labelling emotions.

The results from Experiment 1 and 2 suggest that older adults perform poorer than younger adults on negative emotion identification in a single modality. Next experiment will explore whether older adults can compensate for their difficulties in processing emotion only from faces or only from voices through multisensory integration.

Experiment 3: Cross-modal Emotion Matching

Introduction

Our everyday experience of decoding emotions from other people generally involves a simultaneous combination of visual and auditory cues and it remains unexplored whether simultaneous presentation of auditory and visual cues to emotion benefits affect recognition performance in older adults. One previous study investigated age differences in the ability to match emotional faces to voices and found that matching emotional sounds to angry, sad and disgusted faces proved to be more difficult for older adults than younger adults (Sullivan & Ruffman, 2004). However, Sullivan and Ruffman (2004) used a methodology in which participants heard an emotional sound (a passage read in an emotional tone or a non verbal expressive sound) that lasted for 20 seconds. Once the sound stopped participants then had to match the sound to one of six different facial emotions presented on a computer screen. In the current experiment, participants had to match if emotional stimuli presented on the face and in the voice are the same or different. Given evidence from non-emotional stimuli that older adults may be able to compensate for problems in processing single modality stimuli through multisensory integration (Laurienti et al., 2006), the current experiment aims to explore whether older adults benefit from congruent multisensory information about emotions.

Cross-modal information is beneficial to processing only when the information presented in both modalities is congruent. When information from one modality contradicts the other, this compromises processing of target information, resulting in slower reaction times and lower accuracy (Meredith & Stein, 1986, 1996). This pattern also occurs when incongruent audio-visual information relates to emotional stimuli, as for instance perception of facial emotional expression can be altered by vocal information representing a different emotion (Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007; Ethofer et al., 2006). Understanding age effects on the processing of congruent and incongruent visual and auditory emotional information will shed more light on social processing in older adults. For instance, it is important to be able to judge whether cross-modal information is congruent, as it is an indicator that emotion portrayed in both channels is genuine whereas problems in detecting incongruence might indicate lack of sensitivity to identify deceit.

Hence, Experiment 3 directly addresses age differences on an emotional cross modal matching task where participants hear and see emotional information simultaneously from faces and voices, and must decide whether the information is congruent or incongruent.

Aims of Experiment 3

It was predicted that older adults would perform as well as younger adults on congruent matching tasks where both auditory and visual emotional information were presented concurrently, as they would benefit from multisensory integration. However, given well-documented difficulties with controlled inhibition of irrelevant information in older adults (Hasher & Zacks, 1988), older adults were predicted to perform more poorly than younger adults on the cross-modal incongruent trials.

Method

Participants

The same 50 participants described in Experiment 1 took part in this experiment.

Materials

For this auditory and visual cross-modal paradigm, the series of faces adopted from Facial Expressions of Emotion: Stimuli and Test (FEEST*;* Young et al., 2002) and the prosodic emotional stimuli from Montreal Affective Voices (Belin et al., 2008) were used as described above. Participants were presented with an emotional expression on a face at the same time as a prosodic emotional interjection. Emotional faces (2 male and 2 female) taken from Facial Expressions of Emotion: Stimuli and Test (FEEST*;* Young et al., 2002) were paired with actors' voices (2 male and 2 female) from the Montreal Affective Voices (Belin et al., 2008) in a way that a particular face always appeared with same gender corresponding prosodic expression.

In the congruent trials, 6 facial emotions (anger, fear, disgust, sadness, happiness and surprise) were paired with matching corresponding prosodic expressions, for instance 'happy'-happy, 'sad'-sad. Face-voice pairings for each of the six emotions were repeated 4 times, giving a total of 24 congruent trials. In the audio-visual incongruen*t* trials, the same 6 facial emotions were presented 4 times but with a nonmatching prosodic expression e.g. 'happy'-sad, giving again a total of 24 incongruent trials. In the incongruent trials, the facial emotion-prosodic expression pairings were different each time. Each negative emotion presented on the face (fear, sadness, disgust and anger) was paired once with happiness and once with surprise (in other words once each with the two positive emotions) and paired in the remaining two trials with two of the other negative emotions (randomly allocated). Positive emotions presented on the face (happiness and surprise) were paired once each with the four negative emotions (disgust, sadness, anger and fear) presented in the voice. Each emotional voice in the incongruent face-voice pairings was presented 4 times across all the trials. Following the methods of previous experiments in this field of multisensory congruence detection, e.g. Laurienti, Kraft, Maldjian, Burdette, and Wallace (2004) we also included some control trials. In these *control* trials, 6 facial emotions (anger, fear, disgust, sadness, happiness and surprise) were presented without a prosodic stimulus and were repeated 4 times, giving a total of 24 control trials.

In order to be comfortable with the task, participants performed 6 practice trials. The stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA). The visual stimuli were presented in the middle of a computer screen and the auditory stimuli were presented through headphones. Each trial started with a 2s fixation cross in the centre of the screen. The audio-visual stimuli were then presented in synchrony, where the visual stimuli were presented for a maximum of 1000 ms and the auditory stimuli was presented for no longer than 450 ms. Participants were asked to attend to the emotional expression on the face and identify whether the audio-visual stimuli were congruent, incongruent or face-only control trials by pressing one of three response buttons, responding as quickly and accurately as possible. The dependent variable was the percentage accuracy for each condition. The order of the stimuli was randomised (see Appendix 4 for test instructions).

Results

The percentage of correct responses for each age group (young versus old) in each of the conditions (congruent, incongruent and control) are illustrated in Figure 2.2. A mixed 2 (age) x 3 (condition) ANOVA was conducted on the percentage of correct responses.

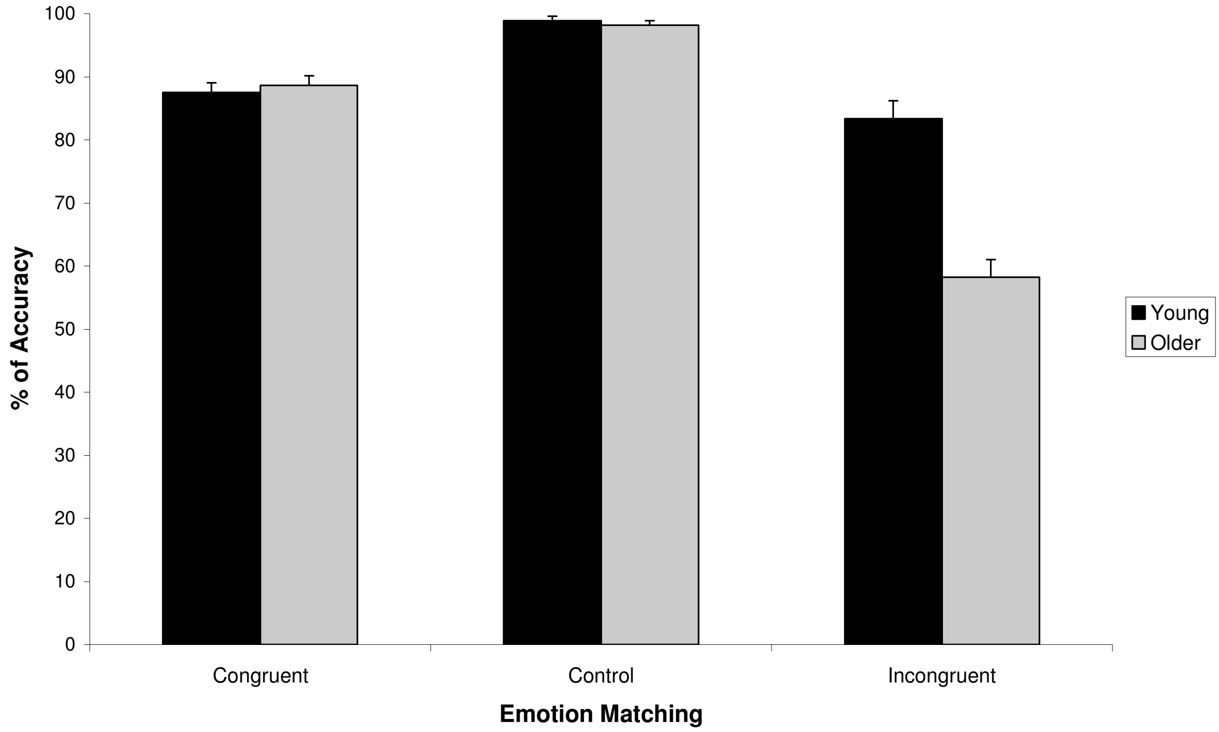

Figure 2.2. Percentage accuracy scores for both age groups performing the cross-modal emotion matching task. Error bars indicate standard errors of the mean

There was a main effect of age, $F\,(1, 48) = 33.87$, $p< .001$, $\eta_p^2 = .41$ with older adults performing significantly more poorly than younger adults. The results also showed that there was a main effect of condition, $F\,(2, 96) = 101.39$, $p < .001$, $\eta_p^2 = .68$ and pair wise comparisons with Bonferroni adjustment revealed that the congruent condition was more accurately performed than incongruent (p < .001). However, the face-only control condition had a higher accuracy rate than the congruent condition (p < .001), or incongruent condition (p < .001). The interaction between age and condition was also significant, $F\,(2, 96) = 27.78$, $p < .001$, $\eta_p^2 = .37$.

Independent sample t-tests revealed that younger and older adults did not significantly differ in either matching faces to voices in the congruent condition, *t* (48) = -.54, p= .59 or in the face-only control condition, *t* (48) =.71, *p*=.48. However, in the incongruent condition younger adults performed significantly better than older adults, *t* (48) = 6.26, *p* < .001. Note that because the incongruent trials involved many different pairings of emotions we did not have sufficient statistical power to investigate an age by emotion interaction for this task.

In order to ensure that older adults did not simply perform well on the congruent condition due to a bias to press the congruent response button when performing the task, response bias (criterion β) and sensitivity (d') using *Signal Detection Theory* (for a review see Swets, 1996) on the congruent and incongruent trials were measured. Older and younger adults did not significantly differ in terms of response bias (*M* = 1.98, *SD* = .86; *M* =1.45, *SD* = 1.12 respectively), *t* (48) = -1.82, *p* = .07, and therefore there is no age-related bias in responding to the stimuli. However, there was a significant difference between younger and older adults in the sensitivity parameter d' (*M* =2.25, *SD* = .38; *M* =1.46, *SD* = .55 respectively), *t* (48) = 5.89, *p* < .001, suggesting that younger adults were more sensitive in discriminating the difference between congruent and incongruent stimuli than older adults.

Discussion

The overall findings support experimental prediction that older adults would perform as well as younger in matching faces to voices in the congruent emotion condition but would be impaired in the incongruent emotion condition. These results suggest that, in line with findings for non-emotional stimuli (Laurienti et al., 2006), older adults may benefit from cross-modal emotional information when information from both modalities are congruent. In contrast, older adults had particular difficulty in identifying when two sources of emotional information are incongruent, which may link to more general difficulties in processing conflicting information in old age.

The findings from Experiment 3 that older adults perform well in matching congruent emotional information across different modalities fits with the hypothesis that older adults can benefit from congruent multisensory information (Laurienti et al., 2006). One important issue which cannot be addressed by the current data is whether the provision of cross-modal information might help older adults to explicitly identify emotions as compared to the situation where only a single modality of information is available. This is the topic of the next experiment (Experiment 4).

Experiment 4: Cross-modal Explicit Emotion Identification

Introduction

Relatively few studies have investigated integration of emotional cues presented in the audio and visual channels (see Campanella & Belin, 2007; Collignon et al., 2008). Nevertheless, it has been postulated that congruence between facial emotion and voice prosody facilitates reactions to stimuli (e.g. de Gelder & Vroomen, 2000; Ethofer et al., 2006). For instance, congruent cross-modal presentation of a fearful voice facilitates recognition of a fearful facial expression (de

Gelder et al., 2001). However, our knowledge of whether multisensory processes related to social stimuli are influenced by aging remains limited.

The finding from Experiment 3 which suggests that older adults perform well when matching congruent emotional information across different modalities fits with the hypothesis that older adults can benefit from congruent multisensory information (Laurienti et al., 2006). This experiment investigates whether older adults benefit from cross-modal information in explicit emotion identification. Given ceiling levels in performance on positive emotions, only negative emotional stimuli were used, i.e. sadness, disgust, fear and anger.

Aims of Experiment 4

The hypothesis in the current experiment was that older adults would perform as well as younger adults in identifying emotions when bimodal presentation of congruent faces and voices were presented at the same time. This should contrast with poorer performance than younger adults when emotions were presented only in one modality i.e. faces and voices on their own.

Methods

Participants

Forty right handed healthy volunteers were recruited through the volunteer databases held at University of Edinburgh and the University of Aberdeen: 20 younger adults (8 men, 12 women) aged between 18-23 years with a mean age of

20.00 years (*SD* = 1.48) and 20 older adults (10 men, 10 women) aged between 63-78 years with a mean age of 70.55 years (*SD* = 4.12). All participants performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997). Older and younger adults did not significantly differ in their verbal ability (M = 108.50, SD = 5.58; M =111.15, SD = 4.05 respectively), t (38) = 1.72, p= .09. However, in terms of speed of processing older adults performed significantly slower than younger adults, (M = 44.60, SD = 10.34; M =64.35, SD = 10.15 respectively), t (38) = 6.09, p < .001. Two groups did not differ significantly with regard to gender, χ^2 (1, 40) =.40, p=.53. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the Wechsler Adult Intelligence Scale-III UK selection criterion (Wechsler, 1997).

Materials

A cross-modal paradigm was devised using visual and auditory emotional information. The visual stimuli were taken from the Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002) series of ten faces (five male, five female) portraying four negative emotions: fear, disgust, sadness and anger

The corresponding prosodic emotional stimuli for anger, sadness, fear and disgust were adopted from Montreal Affective Voices (Belin et al., 2008) which take the form of short non-linguistic interjections of the vowel /a/. Participants were asked to identify which emotion was portrayed on the face, in the voice or face and voice combined together by pressing ‘A’ for anger, ‘S’ for sadness’, ‘D’ for disgust or ‘F’ for fear (see Appendix 5 for test instructions). The visual stimuli were presented for maximum of 1000ms and auditory stimuli were presented for no longer than 450ms, as in the previous experiment.

The audio-visual stimuli were presented in synchrony (SOA= 0 ms) and the emotion presented on the face matched the emotion presented in the voice. The paradigm contained 40 congruent pairs of emotions presented cross-modally, 40 emotions presented visually and 40 auditory emotions giving a total of 120 trials. Therefore, in each of the conditions visual, auditory or audio-visual each emotion (anger, sadness, disgust and fear) was presented ten times. Participants were instructed to respond as quickly and accurately as possible. The sound level was adjusted to be comfortable for each participant and participants were seated approximately 50 cm from the visual display. Prior to performing the task, participants performed 8 practice trials. The dependent variables were the percentage accuracy for each type of trial i.e. audio-visual, visual only and auditory only. Participants completed a single block of trials including visual, auditory and audio-visual trials. The order of the stimuli was completely randomised. The stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA).

Procedure

All participants in this experiment performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the Digit Symbol Substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing. In addition, older adults performed the screening tests described in Experiment 1 to rule out cognitive and perceptual problems: the Mini Mental State Examination (MMSE; Folstein et al., 1975), the Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983) and the Florida Affective Battery: Subtests 6 & 7 (FAB; Bowers et al., 1991).

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. They were reimbursed for any expenses incurred. Informed consent was obtained for all research volunteers according to the Declaration of Helsinki and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee at the University of Edinburgh, and the Psychology Ethics Committee at the University of Aberdeen.

Results

A mixed 2 (age: young and old) x 3 (condition: audio-visual, visual only and auditory only) x 4 (emotions: fear, sadness, disgust, anger) ANOVA was conducted on the percentage of correct responses. Descriptive information for this task is shown in Table 2.5.

Table 2.5. Means and standard deviations for older and younger adults performing the cross-modal emotion recognition task.

	Younger Adults (n = 20)		Older Adults (n = 20)	
	M	*SD*	*M*	*SD*
Facial Emotion Recognition (faces only)				
Fear	95.75	7.48	88.50	14.96
Sadness	89.00	11.65	84.50	17.91
Disgust	96.25	5.82	89.00	13.34
Anger	84.25	14.07	76.50	14.24
Prosodic Emotion Recognition(voices only)				
Fear	81.75	17.11	67.00	21.78
Sadness	98.75	3.19	94.50	9.44
Disgust	96.00	8.20	82.50	14.82
Anger	69.25	20.27	60.50	25.02
Facial and Prosodic Emotion Recognition (faces and voices)				
Fear	95.00	8.88	91.00	15.86
Sadness	97.00	7.33	93.00	7.33
Disgust	98.50	3.66	94.50	7.59
Anger	84.25	14.98	83.50	14.96

The analysis showed that there was a main effect of age, F (1, 38) = 11.15, p = .002, η_p^2 = .23 indicating that older adults performed significantly more poorly than younger adults. This main effect is qualified by the age by condition interaction. There was also a main effect of condition, F (2, 76) = 46.68, p < .001, η_p^2 = .55. Pair wise comparisons with Bonferroni correction showed that audio-visual emotions were easier to recognize than emotions presented separately on the faces (p< .001) or in the voices (*p*< .001). Also, participants found identifying emotions significantly easier from faces than from voices ($p < .001$). There was also a main effect of emotion, F (3, 114) = 33.90, $p < .001$, $n_p^2 = .47$. Pair wise comparisons with Bonferroni adjustment, indicated that sadness and disgust where better recognized than fear (*p*< .001; p= .002 respectively) and anger ($p < .001$). However, fear was better recognized than anger (*p*=.002).

The interaction between age and condition was also significant, F (2, 76) = 4.97, p =.01, $n_p^2 = .12$, as shown in Figure 2.3. Further analysis using independent sample t-tests revealed that older adults performed as well as younger on the emotion recognition task when emotions were presented via auditory and visual modality at the same time, t (38) = 1.58, p = .12. However, older adults performed significantly poorer than younger adults on emotion recognition from faces only, t (38) = 2.55, p = .01 and voices only, t (38) = 3.84, $p < .001$.

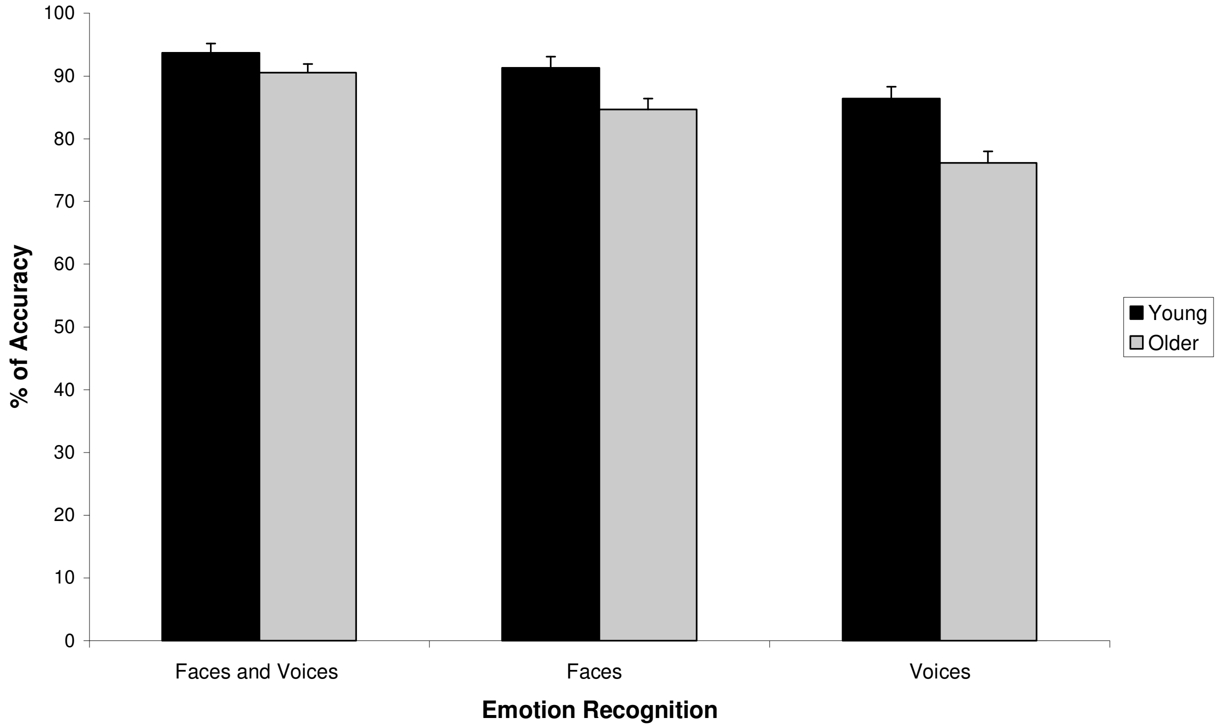

Figure 2.3. Percentage accuracy scores for both age groups performing the cross-modal emotion recognition task. Error bars indicate standard errors of the mean.

There was also a significant interaction between condition and emotion F (6, 228) = 11.72, p < .001, η_p^2 = .24. Further analysis with Bonferroni correction for multiple comparisons revealed that in the audio-visual condition, anger was more poorly recognized than fear (p = .04), sadness (p < .001) and disgust (p< .001). Also, in the picture only condition, anger had lower recognition than fear (p< .001) and disgust (p< .001). In the auditory only condition, anger was also worse recognized than fear (p< .001), sadness (p= .003) and disgust (p< .001), and participants found it easier to identify sadness than fear (p< .001) and disgust (p< .001). The two way interaction between emotion and age, F (3, 114) = .62, p = .60, η_p^2 = .016 and three way interaction between condition, emotion and age, F (6, 228) = 4.78, p = .82, n_p^2 = .01 were not significant.

Discussion

Overall the results of the study support the experimental hypothesis as older adults benefited from congruent multisensory information in interpreting emotions. There were no significant age differences in the cross-modal condition but older adults performed worse than younger adults in conditions where emotions were presented only in one modality, i.e. only faces and only voices. Although the literature directly comparing the effects of age on a single modality is limited, it has been suggested that older adults might perform better on a picture-based task, than an auditory based task (see Isaacowitz, et al., 2007). For instance, de Houwer and Hermans (1994) reported that older adults perform better on emotional tasks with emotional pictures, than emotional sounds. In the current study it was easier for both age groups to identify emotions from faces than from voices and there was no significant interaction between age group and condition (modality). Other results indicate that the recognition of the facial emotion disgust across all conditions had the highest recognition rate, and anger had the lowest.

The results of this study clearly demonstrate that older adults are less accurate than younger adults in the identification of emotions in both visual and auditory modalities. Some theories suggest that this decrement in the recognition of emotion in unimodal channels might lead to social difficulties or inappropriate behaviour and affects successful social interaction (Isaacowitz et al., 2007). However, some theories suggest older adults' emotion regulation increases with age and predict age related improvement in well-being (Carstensen, 2006). This evidence seems rather contradictory, as on one hand older adults are expected to show deficits in social behaviour due to poorer emotion recognition in one modality; on the other hand older adults emotional regulation is better than younger adults. Although older adults perform less well in the identification of emotions in one modality in the laboratory, in real life they are likely to be presented with information across multiple modalities. For example, in social interactions, listeners will not only rely upon auditory information but visual cues from the lips and face, as well as the bodily gestures of the speaker. Indeed, resulting data from Experiments 3 and 4 suggests that when two sources of information are presented at the same time older adults can compensate for their problems in one information channel. Hence, even though emotion recognition in one modality is poorer, emotional well being might be well preserved through multisensory integration and this topic should be directly addressed in future research.

Summary Discussion of Chapter 2

The results from Experiments 1-4 indicate that older adults had difficulty in identifying emotions from faces and voices, in line with previous findings (Ruffman et al., 2008). The novel hypothesis in these studies was that these age differences in emotion perception would disappear when congruent multimodal information was available. Evidence to support this hypothesis was found in two studies. Older adults were as good as younger adults at detecting congruence in cross-modal emotional cues (Experiment 3) and explicitly identifying emotions from cross-modal cues (Experiment 4). Taken together, this evidence indicates that older adults benefit substantially from the provision of multiple channels of information about emotions. Good ability to use congruent sources of information about emotions may benefit older adults in social situations, where more than one modality of information will usually be available.

Results of this study extend to emotional information the finding that older adults can benefit from congruent multisensory information when processing non-emotional stimuli (Laurienti et al., 2006). Although it remains unclear why older adults benefit more than younger adults from multisensory integration, it was initially suggested that it might be due to age related changes in the modulation of attention (Peiffer, Mozolic, Hugenschmidt, & Laurienti, 2007; Laurienti et al., 2006; Alain & Woods, 1999). When younger adults are presented with cross-modal information and attend to one modality, their neural activity for the attended modality is enhanced, whereas their neural activity for the irrelevant modality is significantly decreased. In contrast, because older adults show less suppression of cross-modal information, it was proposed that they have enhanced multisensory integration. However, recent findings of Hugenschmidt, Peiffer, McCoy, Hayasaka, & Laurienti (2009) indicate that enhanced multisensory integration in older adults may not be due to the deficits in cross-modal selective attention. An alternative explanation views multisensory enhancement in older adults as a form of compensatory strategy for age related reduction in the brain activity of the sensory cortex responding to the single modality (Peiffer et al., 2007; Cabeza, Anderson, Locantore, & McIntosh, 2002).

It was also hypothesized that older adults might have difficulty in perceiving incongruency from across different emotional channels, and this was supported by the results from Experiment 3. Poor ability to perceive incongruent emotions from different sensory modalities might impair older adults' ability to understand cues to deception or masking of emotions. The poorer performance of older adults in incongruent cross-modal conditions might be explained in terms of neuropsychological models of aging which postulate that cognitive changes in older adults are due to deterioration of the frontal lobes (e.g. Moscovitch & Winocur, 1995), in particular the dorsolateral prefrontal cortex (DLPFC) where age effects are found on cognitive abilities in working memory and executive abilities (Terry, DeTeresa, & Hansen, 1987; MacPherson et al., 2002). The poorer understanding of cross-modal conflicting emotional cues in older adults may reflect age declines in the cognitive abilities tapping the DLPFC, giving evidence for the role of DLPFC in incongruent cross-modal matching (Plaza, Gatignol, Cohen, Berger, & Duffau, 2008). This issue of age related decline in executive abilities is addressed in Chapter 3 by investigating whether age related declines in dealing with incongruent cross modal integration are specific to social interaction or cognitive control in general.

Conclusion

To conclude, in unimodal paradigms (Experiment 1 & 2) related to facial and prosodic emotion identification, it was found that older adults performed more poorly than younger adults. However, in a task where participants had to match emotional faces to voices (Experiment 3), older adults performed as well as younger when presented with congruent auditory and visual emotional information, but had difficulty in identifying incongruent information. Finally, older adults performed as well as younger adults on congruent explicit cross-modal emotion identification (Experiment 4). The results therefore show that older adults may benefit from congruent multisensory information when interpreting emotions.

Chapter 3: The Effects of Healthy Adults Aging on Cross Modal Stroop Task

Introduction

The results from experiments described in Chapter 2 suggest that older adults benefit from congruent multisensory information when interpreting emotion. In contrast, they detect incongruency less well than younger adults. It remains unclear whether age declines in dealing with incongruent cross modal integration are specific to emotion or reflect general cognitive control deficits. Patient's data suggest that social cognition tasks are related to executive function measures (e.g. Channon & Crawford, 2000; Mah et al., 2005; Phillips et al., 2007), it may be that executive functioning underlies these patient's problems decoding emotions. For instance, Carlson and Moses (2001) proposed that executive functions contribute to the development of socio-cognitive skills while others have suggested they are important for performance on tasks involving social cognition (Leslie, Friedman, & German, 2004; Leslie, German, & Polizzi, 2005).

Moreover age-related general cognitive deficits and emotion recognition are correlated (e.g. Salthouse, 1994, 2000; Orgeta & Phillips, 2008). Despite these correlations, there is also evidence that some patients with poor performance on social cognition tasks perform well on executive tasks (for a review see, Miller & Cummings, 2007). In particular, patients with ventromedial prefrontal cortex (VMPFC) damage tend to perform poorly on tasks assessing social cognition but show preserved performance on tasks tapping the dorsolateral prefrontal cortex (DLPFC) such as executive functioning, working memory, planning, abstract reasoning etc. (e.g. Stone, Baron-Cohen, & Knight, 1998, Mah et al., 2005). In contrast, patients with damage to the DLPFC are impaired on executive functioning but not on social cognition tasks, e.g. recognizing the emotions of others (e.g. Mah et al., 2005). Nevertheless, DLPFC is important for adding structure, logic, clarity and organisation to social cognition (Miller & Cummings, 2007) and executive functioning in social situations plays an important role as: '*the executive demands of real tasks in the social realm can be enormously complex, and executive skills are probably necessary to perform the kind of slow, deliberative logical processing necessary to synthesize implicit, multimodal, often conflicting social information from multiple sources and plan behaviour accordingly'* (Miller & Cummings, 2007, p.356).

If executive functioning plays a role in social abilities, it might be that older adults perform more poorly when matching incongruent faces to voices and unimodal emotion recognition due to age-related executive decline in selective attention. The aim of the studies in this chapter is to investigate the role of executive functioning in matching congruent and incongruent information from different modalities, as well as the role of executive functioning in unimodal emotion recognition. In order to address this, it was necessary to develop a cross-modal Stroop-like paradigm assessing executive functioning without the element of social cognition. This is described below.

The Stroop task

Everyday situations contain numerous sources of information from the environment and therefore mechanisms of selective attention are needed to identify the relevant sensory information which we use to control our current behaviour. Individuals must rely upon their ability to divide their attention when attending to a large number of congruent and incongruent cross-modal sensory inputs. Norman and Shallice (1986) proposed that the coordination of two interfering tasks is controlled by the Supervisory Attentional System (SAS) when a choice of responses is required and the SAS is localised within the frontal regions of the brain. Miller and Cohen (2001) model of cognitive control also suggests that the prefrontal cortex is important in situations where a habitual response is not required and argues that the prefrontal cortex biases certain behaviour, such as those involved in the Stroop task.

In the Stroop classical demonstration (Figure 3.1), participants are asked to read the list of words aloud as fast as possible (only columns 1 and 2) while ignoring the print colour. For columns 3 and 4 the task is changed to naming the print colours aloud, again as fast as possible, ignoring the letters or words.

Figure 3.1. The Stroop task (1935). Adapted from MacLeod and MacDonald (2000, p.384)

As a result of this experiment Stroop (1935) observed three primary results. The first was that reading words was faster than naming the colour of the ink in which the word was printed. The second result reported was of minimal differences between reading the words in black ink and in colour (columns 1 and 2 in Fig.3.1). This suggested that mismatched ink colours did not produce interference in reading words. The third result was that when naming the colour of ink, large differences were observed between reading non-words (column 3) and incongruent colour words (column 4). It is this difference that comprises Stroop interference. Interference costs are calculated by comparing the time to name the ink colour for incongruent colour words (column 4) compared to the time to name the ink colour for nonword stimuli (column 3). The prototypical model of Stroop includes a facilitation effect where participants' colour-naming RTs are faster in the congruent condition where colour and colour word match together (e.g. BLUE printed in blue), than in a control condition (e.g. sssss printed in blue).

Age differences on the Stroop task

Neuropsychological models of ageing postulate that cognitive changes in older adults are due to deterioration of the frontal lobes, thought to play a role in executive function (e.g. Moscovitch & Winocur, 1995). Age related cognitive decline is especially associated with poorer performance on measures of executive function when there is a need to overcome distraction from irrelevant information, i.e. older adults perform poorer than younger adults on the tasks that place high demand on control processes (Hasher, Lustig, & Zacks, 2007; Lusting, Hasher, & Zacks, 2007). Distracters impair older adults' performance on a number of tasks. For instance, older adults are more likely to perform poorly on visual search tasks in the presence of a distracter, (e.g. LePage, Stuss, & Richer, 1999), and this is also the case for memory (Zacks, Radvansky, & Hasher, 1996) and reading tasks (Dywan & Murphy, 1996). General findings suggest that there are age differences in slowing and errors increase with the number of distracters (e.g. Scialfa, Esau, & Joffe, 1998) and older adults are more sensitive than younger adults to distracters presented concurrently (e.g. Maddox, 2001). The classical example of older adults' difficulties in inhibiting irrelevant information is the Stroop task (Stroop, 1935). A number of studies reported age effects on the inhibitory component of the Stroop task (e.g. Le Page et al ., 1999) where older adults performed more poorly than younger adults when they have to name the colour of the ink which is incompatible with the word meaning. This is thought to be due to a defective inhibitory mechanism (e.g. Hasher & Zacks, 1988).

The inhibitory theory of cognitive aging is also supported by neuroimaging research. Numerous studies have reported that general impairment on executive functioning tasks with age is related to structural changes in white matter tracts, neurotransmitter depletion, and atrophy within frontal brain regions (Volkow et al., 2000; Buckner, 2004; Raz, 2005). These brain changes might significantly contribute to the poorer performance of older adults on the measures of tasks assessing selective attention and cognitive flexibility, such as in the Stroop task (1935). It has been well documented that the prefrontal cortex is particularly involved in performance on Stroop tasks within modal and cross-modal tasks (Stuss, Benson, Kaplan, Weir, & Della Malva, 1981; Cabeza & Nyberg, 1997; Peterson et al., 1999; Vendrell et al., 1995; Vohn et al., 2007). Neuroimaging studies showed that the most activated areas while performing colour-word Stroop tasks were located within the frontal lobes. For instance, several studies reported brain activation during performance on the colour-word Stroop task in the anterior cingulate cortex (Adelman et al., 2002; Peterson et al., 1999, 2002); the lateral prefrontal cortex (Peterson et al., 1999, Vendrell et al., 1995), and the inferior frontal regions (Peterson et al., 1999; Adelman et al., 2002). Moreover, some studies reported increased brain activation within the ventromedial prefrontal regions (see review of Cabeza & Nyberg, 1997). Frontal brain region activation was also found in the cross-modal colour word Stroop task where the verbalisation of colour words is presented with congruent or incongruent colour patches. In particular, the brain activation was found in the dorsolateral prefrontal cortex (Plaza et al., 2008), anterior cingulate cortex (Laurienti et al., 2003, Vohn et al., 2007) and the fronto-parietal cortex (Vohn et al., 2007).

Cross-modal Stroop task

Most of the research discussed earlier considers the Stroop effect across one modality such as vision rather than cross-modally. Cowan and Barron (1987) were the first experimenters to investigate cross modal colour word Stroop interference. In this study participants were asked to name colours from a card containing 100 stimuli while listening to an audio tape with a random sequence of spoken words. It was found that colour naming was slower when the spoken words were the incongruent names of the colours from the stimulus card rather than non-colour words or there was no sound. Other studies such as Cowan (1989) and Elliot, Cowan and Valle-Inclan (1998) also tested the Stroop effect cross-modally with colours presented in the visual modality and words in the auditory modality. The results showed that colour naming was slower when colours were paired with auditory colour distracters compared with non-colours. Although the existence of cross-modal Stroop effect has been questioned in the past in terms of whether it is possible to replicate the Stroop effect across two modalities (Miles, Madden, & Jones, 1989), the cross-modal Stroop effect is now well established.

The other evidence that postulates the existence of Stroop effects cross-modally can be drawn from the studies of Meyer and van der Muelen (2000); Stuart and Carrasco (1993) and Damian and Martin (1999) where a cross-modal picture-word Stroop-task was adopted which involves presenting pictures of objects with semantically related or unrelated words. Other studies, e.g. Shimada (1990), tested the effect of the auditory presentation of a word on colour naming and found that the presentation of a colour and a word in the same time course produced large Stroop interference which is consistent with the studies of Glaser and Glaser (1982; 1989); Long and Lyman (1987) and Roelofs (2003). To date, however no study has addressed age differences on the cross-modal Stroop task.

In the current study the same cross-modal paradigm as in Experiment 2 was used. However, the faces and voices were replaced with emotionally neutral stimuli, i.e. colour patches. Verbalisation of colour words was used to create a cross-modal colour-word Stroop effect.

Aims of Experiment 5

The aim of this experiment is to adapt the cross-modal colour-word Stroop task to examine the age differences in performance on cross-modal Stroop task. In line with results of the previous studies (Laurient et al., 2004, Roelofs, 2005) showing that accuracy levels when performing cross-modal Stroop task were at ceiling, the experimental prediction focuses on the RTs. Moreover, as previous research documented (e.g. Hunter et al., 2010, Peiffer et al., 2007, Laurienti et al., 2004) that older adults might benefit more from congruent multisensory integration than younger adults, it is predicted that older adults should respond significantly faster to the congruent cross-modal condition than to the control condition than younger adults thus demonstrating Stroop facilitation. In other words, it is expected that older adults will respond faster to congruent audio-visual information (e.g. hearing 'RED' – seeing red colour patch) than to the control condition (seeing a red patch only). In contrast, there should be no difference in response times between the congruent and control conditions for younger adults. It is also predicted that age effects on Stroop facilitation will be reflected in faster response to congruent cross-modal stimuli than to control (unimodal) stimuli.

Given the large literature on the difficulties which older adults display with controlled inhibition, it is hypothesised that older adults will perform more poorly on the incongruent cross-modal task than the control condition (patch only), and that this Stroop interference effect will be greater for older adults than for younger. Stroop interference is predicted to show greater effects of age in incongruent cross-modal stimuli compared to the control stimuli. Finally, both age groups are expected to perform more poorly on the incongruent than the congruent cross-modal condition displaying cross-modal.congruency effect.

Method

Participants

The same participants as in Experiment 1 were tested. However, one older participant was excluded from the response time analysis due to arthritis.

Materials

The same auditory and visual cross-modal paradigm as in Experiment 3 was used except that the faces were replaced with RED, GREEN, BLUE colour patches and the interjections were replaced by the corresponding spoken English word "red"," green," blue" which were used in the study of Laurienti et al. (2005). The stimuli composed of 3 congruent pairs ("red"-red, "blue"-blue, "green"-green), 3 incongruent pairs ("red"-blue, "green"-red, "blue"-green) and 3 control (red - ; green- ; blue-) – colour patches without spoken stimuli. Each of the congruent, incongruent and control pairs were repeated 8 times giving a total of 72 trials.

In order to have an equal number of colour-word pairings in each condition, only 3 of 6 possible incongruent pairings were used (Roelofs, 2003). The colour patches were presented as coloured rectangles 1.5 cm high and 4.5 cm wide in the centre of the monitor screen. The stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA). Each trial started with a 2 second fixation cross in the centre of the monitor. The visual stimuli were presented for 350ms whereas the auditory stimuli for 450ms. The AV stimuli were presented in synchrony (SOA = 0ms).

Procedure

The visual stimuli were presented in the middle of a computer screen and the auditory stimuli were presented through headphones. Participants were asked to attend to the colour patch and determine whether the audio-visual information was congruent, incongruent or the control condition (only visual information) by pressing an appropriate response button (see Appendix 6 for test instructions).. In order to be comfortable with the task, participants performed 6 practice trials. The dependent variables were the number of errors made and the difference in time in manual-response latencies (e.g. Roelofs, 2005) to perform the congruent, incongruent and control tasks. The order of stimuli was randomised. In each of the task the sound level was adjusted to be comfortable, and participants were seated approximately 50 cm from visual display.

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. They were reimbursed for their time. Informed consent was obtained for all research volunteers and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee at the University of Edinburgh.

Results

The hypothesis in the current experiment was that older adults should respond significantly faster to the congruent cross-modal condition than to the control condition when compared with younger adults thus demonstrating Stroop facilitation effect. It was also predicted that older adults will perform more poorly on the incongruent cross-modal task than the control condition (patch only), and that this Stroop interference effect will be greater for older adults than for younger. Finally, both age groups are expected to perform faster on the congruent than the incongruent cross-modal condition thus displaying cross-modal congruency effect.

Accuracy. The mean percentage accuracy and standard error of the mean for both age groups performing the cross modal colour-word Stroop task are shown in Figure 3.2. The statistical analysis of accuracy was conducted using a mixed 2 (age group: young and old) x 3 (condition: congruent, incongruent and control) ANOVA. There was no significant effect of age, F (1, 48) = .001, p = .97, n_p^2 =.001, or a two-way interaction between age group and condition, F (2, 96) = 2.72, p = .07, n_p^2 =.05. However, there was a main effect of condition on accuracy, F (2, 96) = 3.97, p =.02, n_p^2 =.76. Post-hoc pairwise comparisons revealed that the congruent condition was recognised significantly more accurately than the control condition (p<.02) and incongruent condition (p=.04). However, as participants' performance on accuracy scores was very high it is difficult to interpret these results further.

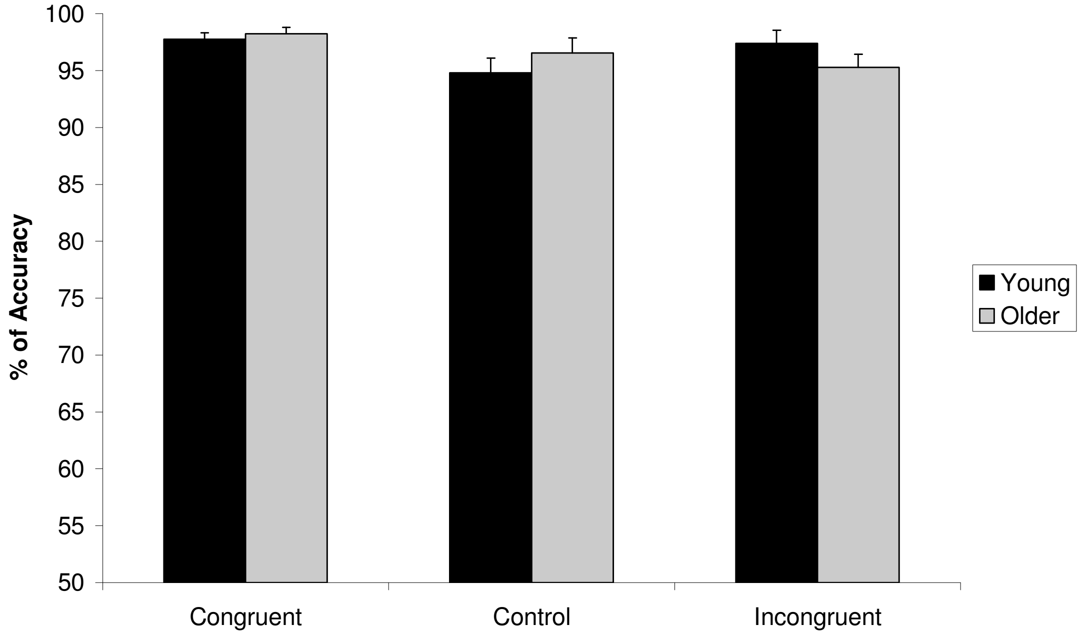

Figure 3.2. The mean accuracy and standard error of the mean for younger and older adults performing the cross-modal Stroop task.

Response Times. The mean response times and standard error of the mean for both age groups performing the cross-modal colour-word Stroop task is shown in Figure 3.3.Analyses of RTs showed a main effect of age, $F\ (1, 47) = 35.77$, $p < .001$, $n_p^2 = .43$, indicating that older adults performed significantly more slowly than younger adults. This main effect was qualified by the age by condition interaction, described in detail below. There was also a main effect of condition, $F\ (2, 94) = 19.19$, $p < .001$, $n_p^2 =.29$. Post-hoc pairwise comparisons with Bonferroni adjustment for multiple tests revealed that time taken to respond to the congruent condition was faster than in incongruent condition, i.e. congruency effect ($p < .001$), and congruent condition was also faster than the control condition, i.e. Stroop facilitation ($p =.01$). However, time taken to respond to the incongruent condition was significantly slower than in the control condition, i.e. Stroop interference (p=.04).

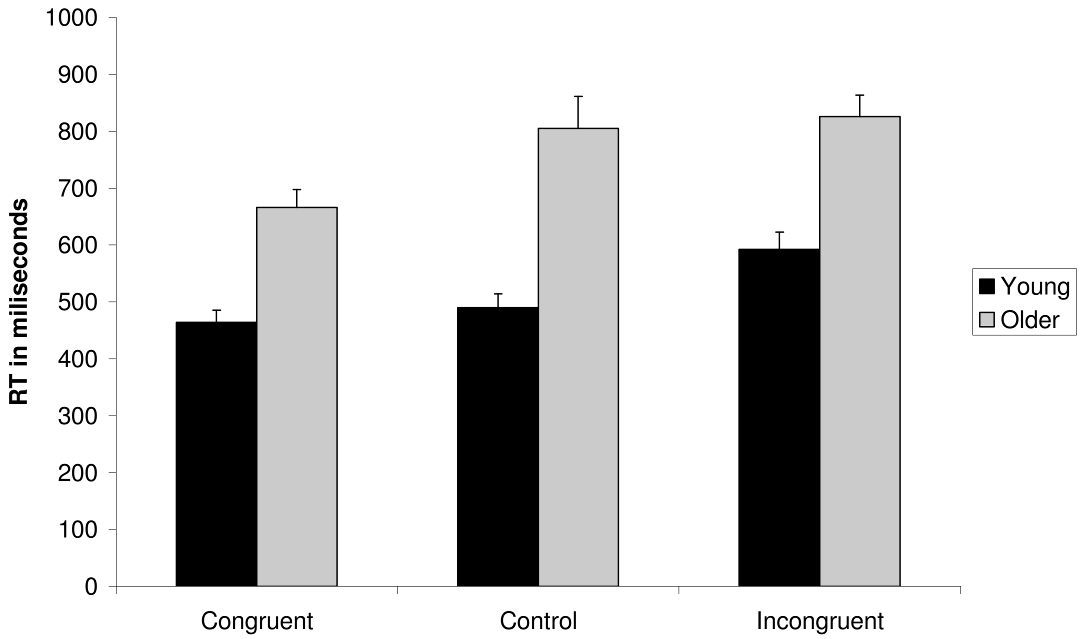

Figure 3.3. The mean response times and standard error of the mean for younger and older adults performing the cross-modal control task.

The interaction between age and condition was also significant, F (2, 94) = 3.15, $p < .05$, $\eta_p^2 = .06$. Analysis of age effects in each condition were conducted using independent sample t-tests. These revealed older adults were slower overall than younger adults in the congruent, t (47) =-5.44; p<.001, incongruent t (47) =-4.77, p<.001 and control conditions, t (47) =-5.21, p<.001. Further analysis showed that there was no significant difference in response times between the congruent and control conditions for younger adults (i.e. no Stroop facilitation effect, t (24) = -1.06, p = .29). In contrast, older adults were faster in responding to the congruent than to the control condition yielding Stroop facilitation, t (23) = -2.93, $p < .001$. Moreover, younger adults were significantly faster to respond to the control condition than to the incongruent condition displaying a Stroop interference effect, t (24) = -4.49, p <

.001. However, older participants did not significantly differ in their response times for the control and incongruent conditions, *t* (23) = -.48, *p* = .64 showing no Stroop interference. Finally for both age groups a similar size cross-modal congruency effect was obtained. In other words, younger adults, *t* (24) =-4.96, *p*<.001 and older adults, *t* (23) =-5.88, *p*<.001 responded quicker to congruent than to cross-modal incongruent stimuli.

Discussion

This study was designed to investigate age differences on cross-modal Stroop effects. The results indicate that there were no age differences on accuracy but that there were significant RT differences. As accuracy levels were almost at ceiling, further discussion focuses on the RTs, which showed that older adults were slower than younger adults under all conditions, and performance on the cross-modal colour-word Stroop task was affected by age. The results support the hypotheses: older adults showed Stroop facilitation, with faster RTs for colour patches and words presented congruently than for colour patches only (control condition). In contrast, there were no differences in responding to the congruent cross-modal and control conditions for younger adults.

The results are in line with the study of Shimada (1990) which also did not find the Stroop facilitation effect when colour words and colour patches were presented in synchrony to younger adults (Shimada,1990). However, younger adults showed the Stroop facilitation effect when an auditory stimuli was presented 300 seconds before the colour patch (SOA=-300). As only older adults respond quicker to the congruent cross-modal condition than the control condition when colour patches and words are presented concurrently, this suggests that older adults benefit more than younger adults from congruent cross-modal information. These results fit with studies reporting that older adults benefit from congruent information when matching non-emotional (e.g. Laurienti et al., 2006) and emotional stimuli (Hunter et al., 2010).

This behavioural increase in performance, i.e. Stroop facilitation can be explained in terms of multisensory integration given evidence supporting the integration of multisensory signals in the brain (Miller, 1982, Stein & Meredith, 1993). A number of studies have indicated that when auditory and visual cues are congruent, they are reflected in behavioural performance, e.g. facilitating RTs (e.g. Meredith & Stein, 1986; Frens, Van Opstal, & Van der Willigen, 1995). It might be that older adults use multisensory integration to compensate for their difficulties in one modality, not only on tasks related to emotions (see Experiments 3 and 4) but also tasks tapping the cognitive domain.

For instance, the study of Laurienti et al. (2006) found that older adults' responses to semantically congruent cross modal information were faster than responses to information presented in one modality, and that older adults benefited more from cross-modal congruency than younger adults. Another study illustrating age-related benefit in multisensory integration was found in a study by Hugenschmidt et al. (2009) suggesting that younger adults do not benefit from multisensory integration when asked to direct their attention selectively to one modality. In contrast, when older adults were asked to attend to one modality while performing congruent cross-modal matching task, they showed increased multisensory integration relative to younger adults. Hugenschmidt et al. (2009) propose that this finding serves as evidence of enhanced multisensory integration with age.

A second aim of this experiment was to look at cross-modal interference. Stroop interference effects were obtained in cross-modal Stroop tasks in the previous studies of Shimada (1990), Elliot et al. (1998) and Glaser and Glaser (1982) with the highest interference when cross-modal information was presented in synchrony (SOA = 0ms), as in the current study. Given the large literature on the difficulties which older adults display with controlled inhibition, it was predicted that older adults will perform more poorly on the incongruent cross-modal task than the control condition (patch only), and that this Stroop interference effect will be greater for older than for younger adults. For instance, it was previously reported that older adults perform especially poorly compared to younger adults under incongruent cross-modal conditions (e.g. Hunter et al., 2010).

The results of the current study suggest that Stroop interference, i.e. responding faster to the control than incongruent conditions, was obtained for younger adults, but not for older adults, which is contrary to our prediction. One reason which would account for the lack of this interference effect might be related to the way the responses were made. Cowan and Barron (1987) and Cowan (1989) reported that colour-word interference depended on spoken responses and such interference might not occur in manual responses. In the current study participants responded only manually. It may be that older adults would show larger interference on spoken but not on manual responses and that only naming the word rather than pressing the button might produce more age related interference on the cross-modal colour word Stroop task. Nevertheless, in Experiment 3, it was demonstrated that older adults performed more poorly than younger adults in terms of accuracy scores on the incongruent condition in cross-modal emotion matching but not on the colour-word Stroop task.

It may also be that these tasks differ in the way that they engage executive control in the aging brain. For instance, the cross-modal emotional incongruent task might require higher levels of executive control, than the cross-modal colour-word incongruent task. Previous studies reported that only tasks which involve more executive (or effortful) inhibitory control are more sensitive to aging, but not tasks which have lower executive control (e.g. Andres, Guerrini, Phillips, & Perfect, 2008; Salthouse, Toth, Hancock, & Woodard, 1997). Finally, both younger and older adults performed more poorly in the incongruent condition than congruent, supporting the existence of a cross-modal congruency effect which has been reported in previous studies e.g. Shimada (1990), Elliott et al. (1998).

In conclusion, the results from the current study demonstrate the effects of age on performance on the cross-modal colour-word Stroop task. Stroop (1935) showed that an incongruent word slowed ink colour-naming, while a congruent word speeded up the response. This effect was replicated cross-modally (Cowan and Baron, 1987; Elliot and Cowan, 2001; Elliot et al., 1998; Shimada, 1990) and re-examined in the present experiment.

Older adults, but not younger adults, performed faster in the congruent cross-modal condition than the control condition, hence displaying cross-modal Stroop facilitation. This suggests that older adults integrate congruent multisensory information better than younger (see also Hugenschmidt et al., 2009). The results may also indicate that older adults benefit more than younger adults from the cross-modal congruent presentation of non-emotional information than information presented only to one modality, as found with emotional stimuli in the previous chapter. On the contrary, younger but not older adults performed faster in the control condition compared to the incongruent condition showing Stroop interference Finally, both younger and older adults showed a similar sized cross modal congruency effect, i.e. responding faster to congruent than to incongruent information.

Social and executive functioning

The second aim of this study is to assess whether individuals' executive abilities might influence performance on social cognition tasks. It is suggested that participants who performed more poorly on matching faces to voices in the incongruent condition would also perform poorer on matching incongruent colour words with colour patches. Moreover, if executive functioning overlaps with abilities to recognize emotions (e.g. Salthouse, 1994, 2000; Orgeta & Phillips, 2008), it may be that poor performance on incongruent cross-modal paradigms such as face-voice matching and colour –word matching will be associated with poorer performance on emotion recognition in one modality, i.e. from faces and from voices, described in Experiments 1 and 2 (i.e. unimodal emotion recognition).

Method

Participants

The same participants as in Experiment 1 took part in this study. However, one older participant was excluded from response time analysis due to arthritis.

Materials

For the correlation analysis the same paradigms described in Experiment 5 (cross-modal color-word Stroop task), Experiment 3 (cross-modal emotional matching task) and Experiments 1 and 2 (unimodal emotion recognition from faces and voices) were used.

Results

The relationship between the cross-modal matching tasks and both unimodal visual and auditory emotional identification was investigated using Pearson correlations. The results from Pearson correlations between within modal emotion recognition and incongruent cross-modal tasks are illustrated in Table 3.1.

Table 3.1. Correlations of overall emotion recognition scores from faces and voice prosody with cross-modal emotion matching task and colour-word Stroop task.

	Facial Emotion Recognition	*Prosodic Emotion Recognition*
Cross-modal Congruent Face-Voice Matching	-.05	-.14
Cross-modal Incongruent Face-Voice Matching	.58***	.49***
Cross-modal Congruent Colour-Word Matching	-.13	.17
Cross-modal Incongruent Colour-Word Matching	.11	.38**
Cross-modal Congruent Colour-Word Response Time	-.41**	-.57***
Cross-modal Incongruent Colour-Word Response Time	-.47***	-.51***

Note: $*p < .05$, $**p < .01$, $***p < .001$

The results of the correlation suggest that none of the unimodal emotion recognition tasks were associated with accuracy performance on the congruent cross-modal condition, i.e. the congruent cross-modal emotional matching and congruent cross-modal colour-word tasks. However, there was overlapping variance between the ability to recognise emotion unimodally (only from faces or voices) and the incongruent cross-modal conditions in both cross-modal tasks (i.e. face-voice emotion matching and colour-voice-matching tasks), suggesting that performance on the incongruent cross-modal tasks is associated with emotion recognition.

The overall analysis revealed that there may be a relationship between the cross-modal tasks (i.e. the emotion matching and colour-word Stroop task incongruent conditions) and performance on unimodal emotional identification. In other words, there was overlap in the ability to recognise emotion from faces and voices with incongruent cross-modal conditions in both cross-modal tasks (i.e. face-voice matching and colour-voice-matching task). On the contrary, none of the emotion unimodal identification tasks were associated with accuracy performance on the congruent cross-modal condition, i.e. congruent cross-modal emotional matching and congruent cross-modal colour-word Stroop task. However, generally individuals, who were faster at matching congruent and incongruent cross modal information, were also better in recognising emotions from voice prosody and faces.

The next correlation looks if the cross-modal emotion matching task (Experiment 3) and cross-modal colour word Stroop task share a common variance with participant's performance (Table 3.2).

Table 3.2. Correlations of cross-modal emotional and colour-word matching task.

Cross-modal	*Colour-Word Matching*	*Colour-Word Response Time*
Face-Voice Matching Congruent	-.03	.10
Face-Voice Matching Incongruent	.36*	-.43**

Note:* $p < .05$, ** $p < .01$

The results suggest that there was no significant association on face-voice matching tasks and colour word matching task in congruent condition. In contrast, the two cross-modal tasks were correlated in the incongruent condition, suggesting that skills involved in matching emotional faces to voices are overlapping with skills important for matching colour-words in the Stroop task, which are thought to assess executive functioning.

Summary of the correlations

Analysis in the current study investigated whether the emotion recognition task and the cross-modal emotion matching task depend on more general executive functioning such as selective attention or response inhibition which is assessed by Stroop task. It was found that those participants who performed well on emotion identification in both unimodal tasks were more able to distinguish when information from faces and voices about emotion was not matching. Moreover, participants who responded faster in the congruent and incongruent conditions in the cross-modal Stroop were also better at recognising emotion from faces. In the same way, participants who were better at identifying emotional voice prosody were also better at matching faces to voices in the incongruent condition. In addition, participants who responded faster to the incongruent cross-modal Stroop task were better in identification emotions from voices. The present study suggests that emotion perception deficits might overlap with general aspects of cognitive functioning.

Although results for the current study might suggest that selective attention (as assessed by cross-modal Stroop task) might play an important role in emotional processing, it would be interesting to investigate this further with a larger sample with a continuous age range. One limitation of this study relates to circadian arousal. It was demonstrated by May (1999) that the performance of older adults could be influenced by age differences in circadian arousal. It was found that age differences in interference were elevated when older adults were tested in the afternoon rather than in the morning. Participants who took part in this study were tested at different times of the day. Consequently, it would important to apply this finding in future research and test older adults at similar times of the day to limit confounding variables.

Conclusion

In conclusion, the results from the current study demonstrated the existence of a cross-modal colour-word Stroop effect and highlighted age related asymmetry in performance on the colour-word cross-modal Stroop task. Older adults, but not younger adults, performed faster in the congruent cross-modal condition than the control condition, hence displaying cross-modal Stroop facilitation. In contrast, younger but not older adults performed faster in the control condition compared to the incongruent condition showing Stroop interference. Finally, both younger and older adults showed a similar sized cross modal congruency effect, i.e. responding faster to congruent than to incongruent information. It was also found that certain aspects of social cognition, such as recognizing emotions might be related to general cognitive functioning such as selective attention or response inhibition in particular.

Chapter 4: Age, Eye Movements and Emotional Matching

Introduction

The results from Chapter 2 indicate that older adults perform less well than younger adults when they have to integrate incongruent audio-visual information. It has been proposed that older adults' poorer ability to detect incongruence might be due to well documented difficulties to inhibit incongruent source of information (e.g. Hasher & Zack, 1988). However, there might be other underlying reasons contributing to older adults' difficulties in detecting cross-modal emotional incongruence such as age related changes in gaze behaviour when looking at the emotional faces. For instance, when people are matching emotional information on the face with emotional information in the voice, they have to look at different facial features, such as the eyes which are an important source of emotional information or the mouth which is a source of a sound or speech. Therefore, it might be that older adults look differently than younger adults at emotional faces when presented with an incongruent voice.

As most research on audio-visual integration has focussed on speech perception (e.g. Kavanagh & Mattingly, 1972, McGurk & MacDonald, 1976; Meredith & Stein, 1986), with little as yet on emotion perception, this chapter begins by reviewing the former with an aim of extracting principles which may apply to cross-modal emotion perception. As reviewed in Chapter 2, the judgment and understanding of emotion in others during social interaction requires integration of inputs from multiple modalities, in particular vision and audition. Perception of speech and emotion recognition both commonly require integration of information from visual and auditory channels (de Gelder & Vroomen, 2000).

In their now classic study on speech perception, Sumby and Pollack (1954) found that in a noisy environment seeing a speaker's face enhanced the understanding of speech compared to a speech-only presentation. Moreover, facial movements can alter processing of speech information (McGurk & MacDonald, 1976). For instance, in the McGurk task when a visual consonant, e.g. 'g', is dubbed over with a different auditory consonant, e.g. 'b', participants often hear a different consonant, e.g. 'd'. These findings can be related to studies using emotional stimuli, as for instance perception of facial emotional expression can be altered by voice prosody (Kreifelts et al., 2007, Ethofer et al., 2006).

Studies using emotional information similarly find that facial expressions influence judgments, tending to override speech information in incongruent conditions, e.g. when a male actor is showing a happy face but is saying 'please' in an angry voice he is then judged as happy (Massaro & Egan, 1996). Most studies investigating the integration of affective information have paired emotional expressions presented on the face with spoken words or non-linguistic affective bursts (Collignon et al., 2008; Balconi & Carrera, 2005; de Gelder & Vroomen, 2000; de Gelder, Vroomen, & Weiskrantz, 1999; Massaro & Egan, 1996). When participants are asked to judge emotions on the face when presented at the same time with incongruent voice, they perform less accurately and are slower than in condition where face-voice pairings are congruent. (for review, see Chapter 2).

Visual cues to facial affect

A core question in facial emotion recognition research is understanding which cues are used in perceiving emotion on the face. There is no agreement on this issue some researchers suggest that information from the whole face is processed (de Gelder, Teunisse, & Benson, 1997), whereas others stress that most information comes from a small set of salient features for emotion recognition, especially the regions surrounding the eyes and mouth (Ekman & Friesen, 1976). Support for the whole-face position was presented by de Gelder et al. (1997) using an inverted-face paradigm to disrupt whole-face perception. These authors found that participants had difficulties in recognition of facial expressions presented on an inverted face. This suggests that whole face configurations are important for at least some elements of emotion. Support for the restricted-regions model comes from the Facial Action Coding System (FACS; Ekman & Friesen, 1976). This identifies muscle activation during facial processing as largely restricted to the eyes and mouth in emotion recognition as opposed to other facial features. Eye tracking studies have found that anger, fear, surprise, sadness are most sensitive to eye-information, while disgust and happiness rely more on the mouth (Sullivan, Ruffman, & Hutton, 2007). In the majority of studies, looking at the eyes is found to be of particular importance (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001, Dalton, Nacewicz, Alexander, & Davidson, 2006). The importance of looking at the eyes in emotion recognition was especially advocated in studies of autism using eye-tracking. It is well documented that emotion recognition impairments in people with autistic spectrum disorder might be related to their tendency to ignore information in the eyes

(Baron-Cohen, Wheelwright, & Jolliffe, 1997, Pelphrey et al., 2002, Dalton et al., 2005, 2006, Spezio, Adolphs, Hurley, & Piven, 2007).

Gaze disorders and social situations

It was found that preferential looking at the eyes is present in neonates and young infants (Maurer & Salapatek, 1985; Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2001) and this preference develops at a very young age. In fact, '*almost from birth, infants show a fascination with the eyes over other regions of the face, and, by the age of 4 months, can discriminate direct from advert gaze*' (Mason, Hood & Macrea, 2004, p.637). Moreover, Walker–Smith, Gale, and Findlay (1977) found that healthy adults in social situations fixate on the eyes an average of 70% of the time, followed by smaller percentages of fixations towards the nose and mouth. People who tend to fixate more on the eyes than other facial areas are perceived by others in social situations as more intelligent (Wheeler, Baron, Mitchell, & Ginsburg, 1979) and trustworthy (Hemsley & Doob, 1978). Finally, when identifying basic emotions, the eyes have been identified as the most informative facial feature (Baron-Cohen, Wheelwright, & Jolliffe, 1997).Therefore, looking at the eyes is beneficial in social situations. The other evidence suggesting that looking at the eyes might be of particular importance in social situations comes from studies looking at abnormal gaze behaviour in patient populations.

It is well documented that abnormal face gaze contributes to impairment in social situations. For instance, it was reported that less looking at the eyes contributes to impairment and misunderstanding of social interactions, social behaviour and the emotional states of others (e.g. Baron-Cohen, Campbell, Karmiloff-Smith, Grant, &

Walker, 1995). For example, people suffering with autism tend to look more at the mouth and periphery of the face than in the region of the eyes when compared to a healthy control group (Klin, Jones, Schultz, Volkmar & Cohen, 2002) and ignore information deriving from eye gaze (Baron-Cohen et al., 1997). It has also been reported that people with social phobia or schizophrenia tend to avoid eye-contact and do not fixate on the eye region (Horley, Williams, Gonsalvez, & Gordon, 2004; Williams, Loughland, Gordon, & Davidson, 1999). Moreover, the recent aging literature suggests that the poorer ability of older adults to judge some emotions from faces is due to gazing less at the eye region than younger adults (Sullivan et al., 2007; Murphy & Isaacowitz, 2010).

Age effects on gaze patterns in emotional processing

The aging studies on emotion perception have found that older adults perform less well in facial emotion recognition than younger adults (for a review see, Chapter 2). It was suggested that one of the mechanisms underlying those age differences might be related to the way older people look at the faces and eyes in particular. Two recent studies by Sullivan et al. (2007) and Murphy and Isaacowitz (2010) used eye tracking to examine the gaze patterns of younger and older adults during an emotion recognition task. Both studies found that younger adults looked more at the eyes than the mouth when identifying emotions whereas older adults looked more at the mouth area. This suggests that the poorer performance of older adults on emotion identification from faces only, described in Chapter 2, may be associated with looking less at the eyes. Although older adults look less at the eyes while judging emotions from static faces, judging emotional states of others in everyday situations also involves use of information presented in the voice.

Do voices help us to recognize emotions?

In social situations people typically see a face and hear a voice concurrently. While the face and especially the eyes might be a primary medium of emotion information (e.g. Baron-Cohen et al., 1995), auditory information from voice prosody is also likely to facilitate emotion recognition. For instance, in a recent study by Hunter et al. (2010), it was reported that despite problems in identifying emotions presented in one modality, older adults performed as well as younger adults on emotion matching tasks where congruent information from faces and voices was presented at the same time. However, the accuracy of older adults was significantly poorer than younger adults in an incongruent audio-visual emotion matching task. Little is known about why older adults perform as well as younger adults when cross-modal information is congruent but they perform much poorer when information is incongruent.

One potential explanation is that when a voice is added to an emotional face it may influence the way that younger and older adults look at the facial features in the congruent and incongruent conditions. Therefore, eye-movement analysis is a useful tool to study age effects on congruent and incongruent cross-modal emotional information. It allows researchers to record eye movements when the eyes are redirected to a new location (saccades) and when information is attended to (fixation) (e.g. Land, 1999).

It has been demonstrated in studies using non-emotional stimuli that the visual system is very proactive in seeking new information in the environment. For instance, eye movements respond not only to visual but also to auditory input, e.g. sound can initiate the saccadic and smooth pursuit eye movement (Engelken & Stevens, 1989; Sekuler, Sekuler, & Lau, 1997) and eye movement latencies toward a visual target are reduced when the visual target is spatially and temporary concurrent with auditory stimuli (Frens et al., 1995). However, to our knowledge, none of the studies to date have considered how auditory stimuli paired congruently and incongruently with visual cues might influence the way how younger and older adults look at facial features while performing a cross-modal matching task.

It may be that voice prosody congruent with emotion presented on the face might facilitate gaze direction to the most important facial features for cross-modal matching, i.e. the eyes and mouth and benefit accuracy. In contrast, in an incongruent condition when the emotion presented on the face does not match the emotion presented in the voice, older and younger adults might spend more time looking at the different facial features in order to detect incongruence. Moreover, considering the evidence that older adults perform poorer on the detection of cross-modal incongruence than younger adults, it may be that older adults do not scan faces in the same way as younger adults while judging accuracy. In other words, the aim of this study is to investigate if the poorer performance of older adults in identifying emotions from incongruent stimuli is related to the way that older adults look at the different facial features i.e. the eyes, mouth and periphery of the face when compared with younger adults.

Here the adaptation of the task of Hunter et al. (2010; Chapter 2, Experiment 3 of this thesis) will be used to examine eye gaze patterns during a cross-modal emotional matching task. Participants will judge facial emotions presented with either congruent (the faces match the voices) or incongruent voices. In line with previous studies (Hunter et al., 2010, Chapter 2), it is expected that older adults will perform less accurately than younger adults in the incongruent, but not in the congruent condition. It is also predicted that both groups will show longer gaze durations at the faces in the incongruent than the congruent condition. This prediction is in line with other studies that have used non-emotional stimuli and shown that when information is congruent it not only benefits participants' accuracy, but decreases eyes movement latencies towards the visual target, when compared with incongruent cross-modal condition (Frens et al., 1995; Meredith & Stein, 1986).

The other aim of this study is to explore whether fixating on the eyes and mouth benefits accuracy. In line with Ekman and Friesen (1976), it is predicted that gazing at these areas will increase accuracy for both ages, and in both conditions. It is further predicted that gazing at both the eyes and mouth will maximize accuracy, based on the hypothesis that these areas provide independent cues to emotion (e.g. Buchan, Paré, & Munhall, 2007). Hence, in order to be accurate, participants have to fixate on the eye region, as well as match emotion in the gaze with the voice coming from the mouth. It might be that the poorer performance of older adults in detection of cross-modal incongruence is related to differences in how younger and older adults look at facial features while decoding emotions.

Aims of Experiment 6

The aim of this experiment is to investigate whether processing of cross-modal congruent and incongruent social information is related to differences in gaze behaviour in older and younger adults.

Method

Participants

Initially, 30 healthy young and old adults were recruited through the volunteer database held at University of Edinburgh. However, six participants in total were excluded from the study. In this instance it was not possible to carry out eye-tracking with participants who were wearing eyeglasses with reflective frames, as these make it difficult to capture the pupil to be tracked (e.g. Isaacowitz, Wadlinger, Goren, & Wilson, 2006).

For the final analysis, data from 24 participants was used, 12 younger adults (5 men, 7 women) aged between 18-40 years with a mean age of 23.5 years (SD = 3.23) and 12 older adults (4 men, 8 women) aged between 60-79 years with a mean age of 68.17 years (SD = 4.53). The two groups did not differ significantly with regard to gender, χ^2 (1, 24) =1.50, p=.22. All participants were right handed. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the Wechsler Adult Intelligence Scale-III UK selection criterion (Wechsler, 1997). They performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing.

Older and younger adults did not significantly differ in years of education, t (22) = 5.75, p = .57, or verbal ability t (22) = -.04, p = .97. However, in terms of speed of processing older adults were significantly slower than younger adults), t (22) = 2.91, p = .01. See Table 4.1 for the participants' characteristics.

Table 4.1. Means and standard deviations for the participant characteristics.

	Younger Adults (n = 25)		Older Adults (n = 25)	
	M	*SD*	*M*	*SD*
Years of full-time education	15.75	2.14	15.17	2.79
WTAR	114.08	5.57	114.17	3.88
DSST	62.17	8.89	51.08	9.74

Note: WTAR = Wechsler Test of Adult Reading; DSST = Digit Symbol Substitution Test

Materials

Congruent and Incongruent Emotion Matching Task.

A cross-modal paradigm was devised using visual and auditory social information similar to the cross-modal paradigm described in Experiment 3, Chapter 2. The visual stimuli were taken from the Ekman and Friesen (1975) series of ten faces (five male, five female) portraying four negative emotions: fear, disgust, sadness and anger. The prosodic emotional stimuli were adopted from the Montreal Affective Voices (Belin et al., 2008) which take the form of short non-linguistic interjections of the vowel /a/. Participants were asked to judge if the emotion presented on the face match the emotion presented through the headphones, while measuring their accuracy and fixation duration (see Appendix 7 for test instructions). The audio-visual stimuli were presented in synchrony (SOA= 0 ms). In the congruent condition, the emotion presented on the face matched the emotion presented in the voice, e.g. 'sad'-sad and was presented 40 times (10 times for each emotion). In contrast, in the incongruent condition, the emotion presented in the face did not match the emotions presented in the voice. In the audio-visual incongruent trials, the same 4 facial emotions (sadness, fear, anger, disgust) were presented 10 times each but with a non-matching prosodic expression e.g. 'happy'-sad, giving again a total of 40 incongruent trials (10 times for each emotion). The face voice pairings were different each time as six prosodic emotions (anger, fear, sadness, disgust, happiness & surprise) were used. Each incongruent emotion in the voice was equally represented.

The visual stimuli were presented until participant responded and auditory stimuli were lasted for no longer than 450ms, as in the previous experiment. Each presentation of the stimuli started with a 2 second fixation cross. Participants were instructed to respond as quickly and accurately as possible. Prior to performing the task, participants performed eight practice trials. The dependent variables were the percentage accuracy when responding during the congruent and incongruent conditions. In addition, the fixation time for each individual area-of-interest was measured. The eye tracking apparatus and procedure are described below.

Apparatus

In the current experiment the eye tracking data and button responses were recorded using SR Eyelink1000 eye tracking system. Eye tracking data were recorded at 1000 Hz and eye position was sampled every millisecond. Viewing was binocular but only the right eye was tracked. The experiment was run under WindowsXP (Microsoft Inc.) using Experiment Builder and Eyelink toolbox (Cornelissen, Peters, & Palmer, 2002). Participants' seating was adjusted so their eyes were level with the middle of the computer monitor. Visual and auditory stimuli were delivered by Experiment Builder. The auditory stimulus was presented through headphones. Visual stimuli were presented on the 21 inch monitor screen with refresh rate of 140 Hz placed in front of the participant at an eye-to-screen distance of approximately 90 cm. Images (241 w x 362 h pixel 24 bit photographs) were centrally displayed.

Procedure

A nine point calibration and validation procedure was conducted prior to the experimental trials for each participant. After calibration, participants were presented with the cross-modal task described above. The participants were asked to attend to the emotional expression on the face and decide whether the audio-visual stimuli were congruent or incongruent by pressing one button for congruent and one for incongruent trials. While attending to the faces and performing the cross-modal matching task, the researcher was interested in how participants looked at the faces in the presence of congruent and incongruent cross-modal stimuli.

Three areas of interest (AOI) were defined on the photographs taken from the Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002). Regions of interest were drawn using the drawing functions within the Data Viewer. The procedure for choosing the AOI is in line with previous studies in the area (e.g. Murphy & Isaacowitz, 2010). The first AOI was a rectangle which included both the eyes with the highest extent of the eyebrows. The second area was also a rectangle and contained the entire mouth area starting from below the nose to the chin and the width of the mouth. The third AOI in this study encompassed the area of the full face without the hairline. Fixation time within each area of interest (AOI) was calculated. Eyetracking data were analysed for fixation using EyelinkData Viewer (SR Research, Hamilton, Ontario, Canada) and no minimum duration criterion was set for fixation. Fixations were defined as any time when the eyes were not in a saccade or blink.

All participants in this experiment performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) and the Digit Symbol Substitution (DSST; Wechsler, 1997). In addition, older adults performed the screening tests described in Experiment 1 to rule out cognitive and perceptual problems: the Mini Mental State Examination (MMSE; Folstein et al., 1975), the Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983) and the Florida Affective Battery: Subtests 6 & 7 (FAB; Bowers et al., 1991).

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. They were reimbursed for any expenses incurred e.g. travel. Informed consent was obtained for all research volunteers according to the Declaration of Helsinki and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee.

Results

Accuracy

Cross-modal Emotion Matching

The percentage of correct responses for each age group (young versus old) in each of the conditions (congruent versus incongruent) are illustrated in Figure 4.1. A mixed 2 (age group) x 2 (condition) ANOVA was conducted on the percentage of correct responses.

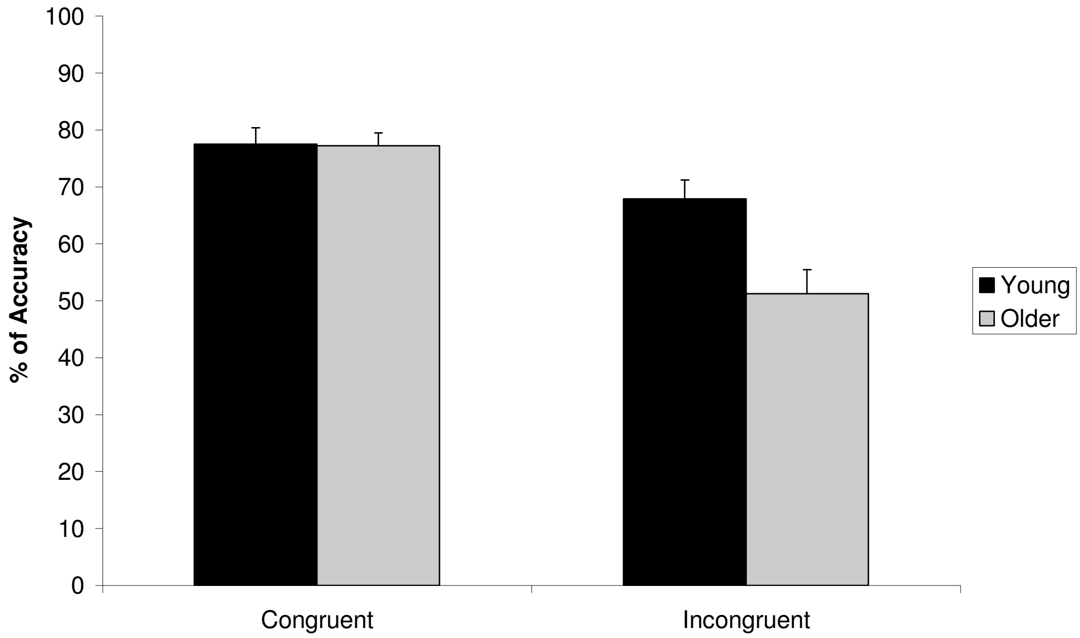

Figure 4.1. The mean accuracy and standard error of the mean for younger and older adults performing the cross-modal matching task.

There was a main effect of age, F (1, 22) = 9.57, $p< .05$, $\eta_p^2 = .30$ with older adults performing significantly more poorly than younger adults. The results also showed that there was a main effect of condition, F (1, 22) = 22.85, $p <.001$, $\eta_p^2 =.51$, with the congruent condition being more accurately performed than the incongruent condition (p<.001). The interaction between age group and condition was also significant, F (1, 22) = 4.87, $p < .04$, $\eta_p^2 = .18$. Independent sample t-tests revealed that the younger and older adults did not significantly differ in matching faces to voices in the congruent condition, t (22) = .47, p=.96. However, in the incongruent condition, younger adults performed significantly better than older adults, t (22) = 3.48, p =.002.

In order to ensure that older adults did not simply perform well on the congruent condition due to a bias to press the congruent response button when performing the task, we measured the response bias (criterion β) and sensitivity (d') using Signal Detection Theory (for a review see Swets, 1996) on the congruent and incongruent trials. Older and younger adults did not significantly differ in terms of response bias (M = 1.59, SD = .80; M =1.35, SD = .53, respectively), t (22) = -.86, p = .40, and therefore there was no age-related bias in responding to the stimuli. However, there was a significant difference between younger and older adults in the sensitivity parameter d' (M =1.28, SD = .39; M = .87, SD = .53, respectively), t (22) = 2.35, p = .03, suggesting that younger adults were more sensitive in discriminating the difference between congruent and incongruent stimuli than older adults.

Fixation Time

In order to investigate if the presentation of congruent and incongruent cross-modal emotional information can influence how younger and older adults look at the facial features, the fixation time of looking at the eyes, mouth and periphery of the face were measured.

A mixed 2 (age: young and old) x 2 (condition: congruent and incongruent) x 3 (AOI: eyes, mouth, periphery of face) ANOVA was conducted on the fixation time. Descriptive information for this task is shown in Figure 4.2.

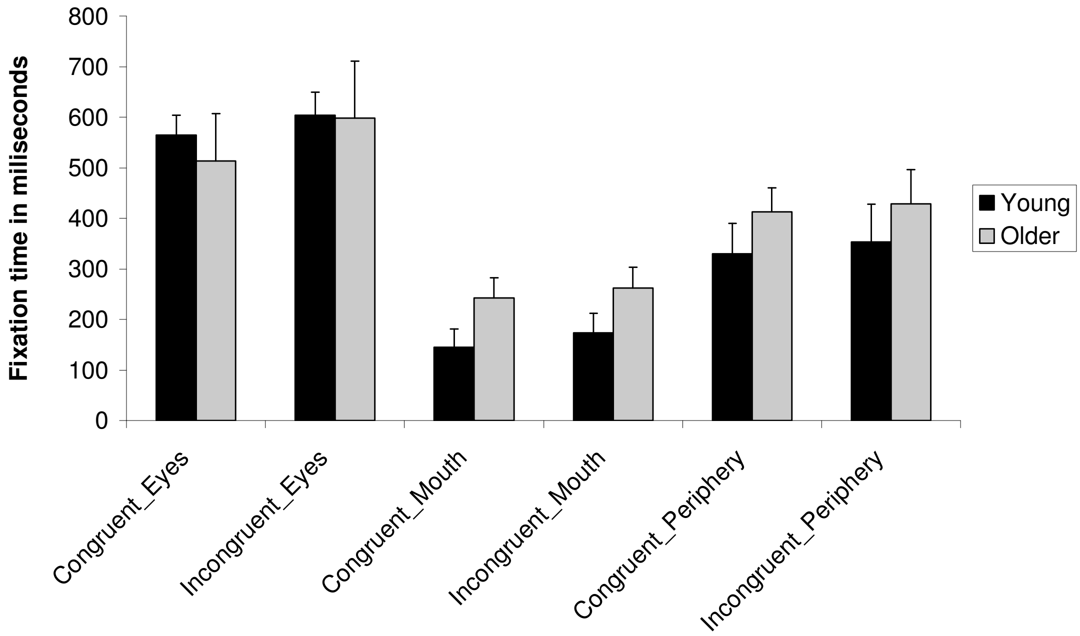

Figure 4.2. The mean and standard error of fixation time on the eyes, mouth and periphery of the face in congruent and incongruent conditions by age group.

The analysis showed that there was a significant main effect of condition, F (1, 22) = 17.54, p <.001, n_p^2 = .44 where older and younger adults spent more time looking at the three areas of interests in the incongruent condition, than in the congruent condition. Moreover, there was also a main effect of fixation time on area of interest (AOI), F (1, 22) = 14.61, p <.001, n_p^2 = .40. The pair-wise post hoc comparison revealed that participants spent more time looking at the eyes than the mouth (p <.001) and the periphery of the face (p =.03). However, participants spent more time looking at the periphery of the face than the mouth (p=.003).

Further analysis showed that there was no main effect of age, F (1, 22) = 1.53, p = .23, n_p^2 = .06 or significant interaction between age group and condition, F (1, 22) = .35, p =.56, n_p^2 = .02 .The interaction between age group and AOI, F (1,

22) = .49, p = .62, η_p^2 = .02, as well as three way interaction between condition, AOI and age group, F (1, 44) = 7.47, p = .48, η_p^2 = .03 was also not significant.

Correlations

In order to investigate whether looking at different facial features benefits accuracy, Pearson correlations between accuracy and gazing at the eyes, mouth, periphery of the face and the whole face for both age groups were performed. The results from the correlational analysis are illustrated in Table 4.2.

Table 4.2. Correlations between the fixation times on each area of interest with accuracy on the cross-modal emotion matching task.

	Accuracy Congruent Condition	*Accuracy Incongruent Condition*
Young (n=12)		
Eyes	.26	-.23
Mouth	-.08	-.49
Eyes and Mouth	.16	**-.56** †

Periphery of the face	.30	.04
Whole Face	**.59***	-.38
Older (n=12)		
Eyes	- .47	**.62***
Mouth	-.19	-.06
Eyes and Mouth	**-.60***	**.60***
Periphery of the face	.23	.08
Whole Face	-.45	**.63***

Note: * $p < .05$, ** $p < .01$, † $p = .056$

The results indicate that older adults who gaze longer at the eye area perform better at detecting cross-modal incongruence than older adults with shorter fixation on the eye region. Please note that the significant association between fixation time on the 'eyes and mouth' and the 'whole face' and accuracy in the incongruent condition is driven by the time older adults spent looking at the eyes. In contrast, there is a suggestion that younger adults who spend less time looking at the eye and mouth areas combined performed more accurately when detecting cross-modal incongruence, as indicated by a nearly significant correlation.

When emotions portrayed on the face are paired congruently with the voice, older adults who looked for a shorter time at the eye and mouth regions combined are better at detecting cross-modal congruence than those older adults who look for longer. In contrast, younger adults who look longer at the whole face: eyes mouth and also at periphery of the face perform best in congruence detection.

It was also found that in the condition where faces are paired congruently with voices, gazing only at eyes region was not related to better accuracy performance in both groups. Likewise time spent fixating on the mouth only area in congruent and incongruent conditions was not related to younger and older adults' ability to accurately match face-voice pairings. Moreover, looking only at the periphery of the face (whole face without eyes and mouth regions) was not associated with higher accuracy for younger and older adults in congruent condition or incongruent condition.

Discussion

The aim of this study is to investigate how younger and older adults look at the facial features important for emotional processing when presented with cross-modal congruent and incongruent emotional stimuli, and whether fixating on particular facial features might benefit accuracy in the cross modal matching task. The accuracy results for the face-voice emotion matching task were in line with previous studies (e.g. Hunter et al., 2010, see also Chapter 2) suggesting that in the congruent condition older adults performed as well as younger adults in matching emotional faces to voices. However, when the information from two modalities was incongruent, older adults performed more poorly than younger adults. Previous studies within the area also indicate that older adults perform as well as younger adults when matching congruent cross-modal information, but perform significantly poorer when they have to detect cross-modal incongruence (for a review see Chapter 2, Hunter et al., 2010).

The analysis of fixation time on different facial features (AOI), i.e. the eyes, mouth and periphery of the face revealed that younger and older adults did not significantly differ from each other in time spent looking at these areas. Both age groups spent less time looking at the facial features in the congruent than in the incongruent condition. This is in line with the studies demonstrating that when information is congruent, it benefits participants' accuracy as well as decreases eye movement latencies towards the visual target. When the information from one modality contradicts the other, this compromises processing of the target information, as well as slows reaction times and lowers the accuracy rate (Frens et al., 1995, Laurienti et al., 2006). Moreover, both age groups looked longer at the periphery of the face than at the mouth. It has been reported that looking at the periphery of the face which is not an expressive feature might also play an important role in gathering some visual information using peripheral vision (Buchan et al., 2007).

The results of this study differ from the findings of Sullivan et al. (2007) and Murphy and Isaacowitz (2010) which reported age differences in eye gaze while judging emotions from faces. Both studies found that younger adults looked more at the eyes than the mouth when identifying emotions whereas older adults looked more at the mouth area. The lack of age effects in patterns of fixations in the current study might be caused by differences in the tasks adopted. In the studies of Sullivan et al. (2007) and Murphy and Isaacowitz (2010), participants were asked to explicitly label emotions presented only in one modality, i.e. in the face, without any auditory stimuli. In contrast, in the current study participants were asked to match whether an emotion presented on the face is the same or different from an emotion presented in the voice. Nevertheless, the results of this study do not support the hypothesis that younger and older adults would differ in their pattern of fixations in emotion matching task. Both younger and older adults spent a similar amount of time looking at the eyes and other facial features such as the mouth and the periphery of face.

Previous studies indicate that gazing at facial features important for social interactions resulted in better accuracy when recognizing the emotional states of others as opposed to not gazing at these features (e.g. Baron–Cohen et al., 1995). In line with Ekman and Friesen (1976), it was also predicted that fixating on the eyes and mouth would increase and maximise accuracy for both age groups in both conditions, based on the hypothesis that these areas provide independent cues to emotion (e.g. Buchan et al., 2007). Therefore the relationship between time looking at facial areas and accuracy on a cross-modal emotional matching task was investigated. It was found that gaze cues from the eyes or mouth alone do not improve younger and older adults' accuracy scores in congruent face-voice matching. Likewise looking at the eyes only was not related to better accuracy judgment for younger adults in the cross-modal incongruent condition. However, older adults who looked longer at the eye area tended to be more accurate in detecting incongruence. Results suggest that in most cases when judging cross-modal emotional information, individuals have to attend to numerous facial features which contain information about emotions. Although information from the eyes is important for understanding emotions and the evidence suggests that people fixate more on the eyes than other facial areas in facial emotion identification (Adolphs et al., 2005), the lower part of the face has also been identified as an important source of visual information about speech and prosody (Yehia, Rubin, & Vatikiotis-Bateson, 1998). In everyday social situations people produce gaze fixation to various facial features (e.g. Paré, Richler, Hove, & Munhall, 2003) to form a unified percept and this is what our results suggest. It was found that when the total fixation time on the eyes and mouth was combined, older adults, who fixate for less time on the eye and mouth regions, performed better on congruency matching. In contrast, younger adults who were more accurate in detecting congruence looked longer at whole faces (eyes, mouth and periphery of the face) than younger adults who looked for a shorter period. Moreover, the poorer ability of older adults in detecting cross-modal incongruence might be driven by the different ways that younger and older adults are looking at the emotional faces. For instance, older adults who looked longer at the eyes only when identifying incongruence tended to perform better than older adults who looked for a shorter period of time. In contrast, younger adults who looked for a shorter time at the eyes and mouth regions combined tended to perform better than younger adults who look at these regions longer.

These results may suggest that younger and older adults differ in the way they look at the facial features in accuracy matching. It may be that detecting congruence for older adults may be more automatic than in younger adults. Perhaps cross-modal congruency helps older adults to direct their gaze straight at the eyes and mouth knowing that looking at these facial features will benefit their accuracy. In contrast, younger adults despite looking at the mouth and eyes have to also look at other peripheral facial features to aid their accuracy. Hence, younger adults who look longer at the faces in the congruency condition perform better.

Analysis of accuracy revealed that older adults performed less accurately on matching incongruent faces to voices than younger adults. It was found that younger adults who spent less time looking at the eyes and mouth tended to perform better at distinguishing cross-modal incongruence, as indicated by the approaching significant correlation. It may be that younger adults, who look longer at the faces, show some degree of confusion, hence performing more poorly than those who do not look for as long. However, older adults who spent less time looking at the eyes only performed more poorly while judging incongruence than older adults who look longer. Knowing that older adults perform more poorly in detecting cross-modal incongruence than younger adults who are looking at the eyes and mouth when judging incongruence, it might be that older adults' accuracy is compromised by looking only at the eyes. If less time looking at the eyes and mouth underlies problems with detection of incongruent cross-modal cues, it may be that training older adults to pay more attention to the eyes and mouth areas might be beneficial when identifying incongruence. For instance, the study of Adolphs et al. (2005) described a patient SM, who suffered bilateral amygdala damage and was unable to recognize certain emotions from faces, fear in particular. When SM. was presented with emotional faces, the eye tracking procedure revealed that SM was predominantly fixating on the centre of the face rather than the eyes (Adolphs et al., 2005). However, when SM was instructed and trained to look at the eye region when judging emotions, she was then able to correctly identify the emotion of fear. Therefore, whether training older adults to look at core facial features for emotional processing could help them in detection of incongruence should be addressed in future studies. It would be interesting to investigate if older adults' performance might be improved if instructed to look only at the eyes and mouth (and avoid looking at the periphery of the face) while judging cross-modal congruence. It may be that lack of age effects when judging congruence is caused by younger adults' inefficient scanning of faces, i.e., looking at the periphery of the face which is silent in emotional information.

The results of this study are in line with the previous literature suggesting that older adults perform as well as younger adults on accuracy measures during congruent conditions. However, older adults perform poorer than younger adults in detection of cross-modal incongruence. Analysis of fixation time looking at facial features revealed that younger and older adults spend a similar amount of time looking at the eyes, mouth and periphery of the face. Both age groups are looking longer at the eyes than the mouth and the periphery of the face. Moreover, younger and older adults looked longer at facial features in the incongruent condition than in the congruent condition.

Further results indicate that when making matching decisions about congruent stimuli, older adults who look less at the eyes and mouth region perform better. In contrast, younger adults who look longer at the whole face perform better in matching cross-modal congruence than younger adults who spent less time looking at the faces. It was also found that looking longer at the eyes is associated with better matching decisions about incongruent stimuli for older adults, yet they are still performing much poorer than younger adults in matching faces to voices. In contrast, younger adults tend to look both at the eyes and the mouth – crucial features for social situations– as we have to look at both the mouth and eyes in order to judge if emotion in the voice (produced by the mouth) matches emotion portrayed by the eyes.

One of the limitations of this study is related to low statistical power, especially for correlational analysis as there are only 12 participants in each group. However, other studies investigating gaze behaviour in social situations also used a small sample of participants (e.g. Klin et al., 2002b, Dalton et al., 2006). For instance, Klin et al. (2002b) studied the fixation patterns in 15 males with autism and 15 controls, whereas Dalton et al. (2006) measured fixation patterns in 12 individuals with autism, 10 of their siblings and 12 control.

Conclusion

Overall results suggest that age differences in the processing of congruent and incongruent visual and auditory social information might be related to changes in gaze behaviour. When emotions portrayed on the face are paired congruently with the voice, older adults who looked for a shorter time at the eye and mouth regions combined are better at detecting cross-modal congruence than older adults who looked for longer. In contrast, younger adults who look longer at the whole face: eyes mouth and also at periphery of the face perform best in congruence detection. Further results show that older adults who gaze longer at the eye area perform better at detecting cross-modal incongruence than older adults with shorter fixation on the eye region. However, younger adults who spend less time looking at the eye and mouth areas combined tend to perform more accurately when detecting cross-modal incongruence.

Chapter 5: Integrating Social Information Following Stroke

Introduction

This pilot study aims to investigate whether changes in behaviour and social interaction often reported in patients post-stroke relate to problems in integrating cross-modal social information and the inability to recognise emotions from faces and voices. It has been reported that in addition to the physical disabilities, changes in personality and behaviour such as irritability, unpredictability and rudeness have been reported in stroke patients (Aybek et al., 2005) from 9 months to one year post-stroke (Anderson, Linto, & Stewart-Wynne, 1995). For instance, the study of Bogousslavsky (2003) study showed that in a sample of 300 stroke patients, as much as 56% of patients post-stroke were more disinhibited; with 27% reporting an increased rate of crying; 24 % being more passive and 11% of patients reported being more aggressive than before the stroke.

Moreover, the study of Stone et al. (2004) looked at the changes in personality traits 9 months post-stroke where 35 carers of stroke patients were asked to rate the severity of behavioural changes following stroke. The study revealed that patients post-stroke were rated by their carers as more irritable and unreasonable than before the stroke. Similar results were found in the study of Anderson et al. (1995) where patients one year post-stroke (n=84) were rated as more unpredictable (35%), having odd ideas (34%) and being more rude (23%). As approximately 130,000 people per year suffer a stroke (Office for National Statistics, 2006) many report a range of abnormal behaviours one year post-stroke, this pilot study has important health and wealth implications. Understanding to what extent problems in combining multisensory information and recognizing emotions might influence social interaction in stroke patients is the first step in designing successful interventions to help stroke patients with their social functioning.

The ability to recognise the emotional states of others plays an important role in social interaction as it indicates how an individual should respond to the emotions of others. However, in order to understand the emotions of others, individuals must successfully integrate information received through multiple sensory channels such as emotional cues from faces and emotional prosody from voices (Russell et al., 2003). As illustrated in Chapter 2, congruent cross-modal information, as opposed to information presented only in one modality, results in behavioural benefits, e.g. produces higher accuracy scores in emotion recognition (e.g. Hunter et al., 2010). However, the integration of incongruent cross-modal stimuli from different sensory modalities can impair one's ability to process relevant stimuli (e.g. Laurienti et al., 2004). The research described in Chapter 2 (e.g. Hunter et al., 2010) has shown that healthy older adults benefit from congruent social information presented to different sensory modalities more than younger adults. It is unknown, however, if stroke patients who display behavioural change post-stroke would also benefit from having the same emotional information presented to two sensory modalities.

Emotion identification and hemispheric hypothesis

The relationship between emotion perception and laterality of stroke lesions has been widely examined (e.g. Borod et al., 1998; Braun, Traue, Frisch, Deighton, & Kessler, 2005; Adolphs, 2002). Studies looking at emotion identification in stroke patients suggested that the right hemisphere might play a more dominant role in perception of emotions than the left hemisphere. For instance, the study of Borod et al. (1998) investigated emotion recognition from faces, voice prosody, and in lexical emotional tasks. It was found that stroke patients with left hemisphere lesions performed well in identifying emotional states through different channels. In contrast, patients with right hemisphere damage were impaired on emotion identification tasks from faces and voices.

However, other research demonstrates that strokes in the right hemisphere do not necessarily impair emotion recognition more severely than those in the left hemisphere. For instance, in the study of Braun et al. (2005), patients with a stroke to the right or left hemisphere did not differ in identifying emotion from faces. Also, it was found that patients with right hemisphere injury were more impaired in visual and auditory perception of emotions, than those patients with left hemisphere damage (Kucharska-Pietura, Phillips, Gernand, & David, 2003). It had also been suggested that the ability to recognize emotions might depend on emotional valence. Studies have reported that patients with both right and left hemispheric damage tend to perform poorer in recognizing negative emotions from faces and voices than positive emotions (e.g. Blonder, Bowers, & Heilman, 1991; Kucharska-Pietura et al., 2003). The lack of consensus on a simple right hemisphere hypothesis highlights that emotion recognition from faces and voices is not a unitary process and requires multiple neural structures which involve both hemispheres (e.g. Adolphs, 2002) and might be modality, task and valence dependent. Although a large proportion of research has focused on difficulties in emotion perception following stroke, only a few studies have examined whether poorer emotion perception underlies the behavioural change often reported in stroke patients. For instance, a study by Hornak, Rolls and Wade (1996) found that patients with ventral frontal lobe damage performed more poorly than patients with non-ventral damage on emotion recognition tasks. The inability to recognize emotions in patients with ventral frontal lobe lesion was associated with behavioural problems experienced by the patients.

Deficits in emotion perception and changes in social behaviour

The changes in social behaviour following stroke might be driven by emotion recognition difficulties. For instance, the inability to recognise emotions is thought to be an underlying cause of changes in personality and behaviour in clinical groups such as frontotemporal dementia (Fernandez-Duque & Black, 2005). Also, studies investigating behavioural changes following traumatic brain injury have suggested that patients are impaired in their ability to understand the mental states of others and identify emotions from faces and voices (e.g. McDonald & Flanagan, 2004, Milders, Fuchs, & Crawford, 2003). Milders, Ietswaart, Crawford, and Currie (2008) argues that '*problems in social behaviour in neurological patients could result from (1) insensitivity to important social cues, such as emotional expressions; (2) impaired understanding of social situations and other people's intentions; (3) failures to adjust one's behaviour in accordance with demands of situation, that is, in flexibility'* (p.319).

This is in line with results from studies with clinical groups such as traumatic brain injury (TBI) or Frontal Variant Frontotemporal Dementia (Fv-FTD) that speculates that changes in social cognition, e.g. emotion recognition deficits may contribute to changes in behaviour (e.g. Kendal & Terry, 1996, Keane, Calder, Hodges & Young, 2002; Milders et al., 2003). Moreover, as results of changes in social behaviour patients might also fail to return to their work and have significant difficulties in social interactions (e.g. Milders, et al., 2003).Yet, despite a significant proportion of patients reporting behaviour change post stroke, it remains unclear whether this is due to difficulty in recognizing emotions per se and/or integration of cross-modal emotional and social stimuli. In order to address this question, it was necessary to use a sensitive measure to find patients who report changes in their social behaviour following stroke.

Assessment of behavioural changes following brain injury

In the current study, the term ‘changes in behaviour or social behaviour’ refers to a range of behaviours which might affect patients’ social functioning due to underlying problems with apathy, disinhibition or executive functioning, which is based on the Frontal System Behavioural Scale (FrSBe; Grace & Malloy, 2002). Table 5.1 illustrates examples of possible changes in social behaviours as a result of apathy, disinhibition and executive functioning based on the FrSBe.

Table 5.1.Examples of changes in social behaviour after stroke based on FrSBe rating form.

APATHY
Speaks only when spoken to.
Has difficulty starting an activity, lacks initiative, motivation.
Neglects personal hygiene.
Sits around doing nothing.
Loses control of urine or bowels and seems unconcerned.
Has lost interest in things that used to be fun or important to him/her.
Starts things but fails to finish them, 'peters out'.
Shows little emotion, is unconcerned and unresponsive.
Is slow moving, lacks energy, inactive.
DISINHIBITION
Is easily angered or irritated; has emotional outburst without good reason.
Does things impulsively.
Laughs or cries too easily.
Makes inappropriate sexual comments and advances, is too flirtatious.
Does or says embarrassing things.
Can't sit still, is hyperactive.
Talks out of turn, interrupts others in conversations.
Get in trouble with the law or authorities.
Does risky things just for the heck of it.
Is overly silly, has childish sense of humour.
Complains that food has no taste or smell.
Swears.
EXECUTIVE FUNCTIONING
Repeats certain action or gets stuck on certain ideas.
Mixes up a sequence, gets confused when doing several things in a row.
Makes the same mistakes over and over, does not learn from past experience.
Denies having problems or is unaware of problems or mistakes.
Is disorganized.
Cannot do two things at once (for example, talk and prepare a meal).
Show poor judgment, is a poor problem solver.
Makes up fantastic stories when unable to remember something.
Says one thing, and then does another thing.
Forgets to do things but then remembers when prompted or when is too late.
Is inflexible, unable to change routines.

It has been extensively reported that changes in social behaviour are often associated with frontal lobe injury (Malloy & Grace, 2005). Since the case of Phineas Gage (Harlow, 1848), researchers have reported a number of patients who show a range of behavioural changes following frontal lesions (e.g. Levin, Eisenberg, & Benton, 1991; Mesulam, 2000) which are also common in cases of frontotemporal dementia (Neary, Snowdon, & Gustafson, 1998), stroke (Stuss & Benton, 1984; Milders et al., 2003) and head injury (Malloy & Aloia, 1998).

In the current study, the Frontal System Behavioural Scale (FrSBe) was used '*as a measure of behaviours associated with damage to the frontal lobes and frontal systems of the brain'* (Malloy & Grace, 2005, p.1).The changes in social behaviour associated with frontal lobe injury are often reported as more disruptive to adaptive functioning (Malloy & Grace, 2005). In a recent in-depth review of five behavioural executive functioning rating scales (Malloy & Grace, 2005), the Frontal Systems Behaviour Scale (FrSBe) was identified as the most well-validated to date. Therefore, for stroke populations, the FrSBe may have particular promise for elucidating the nature and severity of changes in social behaviour (Reid Arndt, Nehl, & Hinkebein, 2007). Nevertheless, a substantial body of research on frontal lobe injury did not focus on behavioural changes associated with frontal lobe lesions, but has concentrated on the development and study of neuropsychological measures designed to assess executive cognitive functions, such as planning, set shifting and response inhibition (Lezak, 1995).

Cognitive deficit and social functioning

According to Wilson, Alderman, Burgess, Emslie, and Evans (1996), the most common impairments following frontal lobe injury are in executive functioning (e.g. disorganisation, problems with abstract reasoning, deficits in planning and forming strategies, impaired attention, concrete behaviour), disinhibition (e.g. impulsivity, loss of social judgment, need for instant gratification) and the syndrome of frontal abulia (e.g., apathy, loss of drive and spontaneity). These cognitive deficits occur in almost half of the stroke population (Hochstenbach, Mulder, van Limbeek, Donders, & Schoonderwaldt, 1998) where attention deficits being the most likely to happen following stroke (Hyndman, Pickering, & Ashburn, 2009). Poorer attention following stroke is also associated with poorer social functioning (McDowd, Filion, Pohl, Richards, & Stiers, 2003). In everyday situations patients will be exposed to numerous stimuli and therefore mechanisms of selective attention are needed to identify relevant sensory information for controlling current behaviour. Individuals must rely upon their ability to divide their attention when attending concurrently to a large number of different within- and cross-modal sensory inputs.

Deficits in attentional processes are also thought to drive problems associated with dysexecutive syndrome. Norman and Shallice (1986) proposed that the coordination of two interfering tasks is controlled by the Supervisory Attentional System (SAS) and that the SAS is localised within the frontal regions of the brain. More recently, neuroimaging studies investigated the coordination of two cross-modal cognitive processes and suggested that the frontal (Brodmann's areas BA 9 and 46) and parietal (BA 40) brain regions are the neural substrates for cross-modal dual-task performance (Szameitat, Schubert, Müller, & von Cramon, 2002; Vohn et al., 2007). Therefore damage to the frontal lobes of the brain should impair multisensory integration.

Aims of Experiment 7

The current study predicts that poorer performance on the FrSBe might be related to difficulties with integration of cross-modal stimuli. Moreover, it is also hypothesized that tasks assessing integration of cross-modal emotional information might be more sensitive to stroke and social behaviour problems than traditional unimodal measures of emotion perception.

Method

Participants

Eight stroke patients (see Table 5.2 and 5.3 for patients characteristics) and 7 gender, age and education matched healthy controls were recruited through the inpatient Stroke Unit at the Royal Infirmary of Edinburgh and volunteer database held at University of Edinburgh respectively: the stroke patients (8 men) were aged between 46-89 with a mean age of 63.50 years (*SD* = 13.78) and the 7 healthy controls (7 men) were aged between 47-79 with a mean age of 66.96 years (*SD* = 6.10). The stroke patients were tested in their own homes and controls at the Department of Psychology, University of Edinburgh. All participants were right handed, English was their first language and the stroke patients had experienced their first episode of ischemic or haemorrhagic stroke based on a CT scan and were tested within one month of discharge from hospital. Patients who had a history of previous vascular incident, head injury or psychiatric or other neuropsychological disorders such as dysphasia, neglect, amnesia or apraxia were not consider eligible to take part in the study. The duration since lesion onset ranged from 27 days to 2 months and 19 days with a mean of 1 month and 29 days (*SD* = 16.15).

Table 5.2. Stroke type and hemispheric localisation (hemisphere of lesion) in a sample of eight stroke patients.

Stroke Characteristics	
Stroke patients	**(N=8)**
Stroke type	
Ischemic	7
Unknown	1
Hemisphere of lesion	
Left	2
Right	4
Bilateral	1
Unknown	1

Stroke patients and healthy control performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing. The two groups did not significantly differ in terms of years of education, t (13) = -1.20, p= .25, or verbal ability, t (13) = -1.35, p = .20. However, in terms of speed of processing, the stroke patients were significantly slower than the healthy controls, *t* (12) = -2.66, *p* = .02. One patient was excluded from the DSST due to weakness on the right hand side.

All patients performed a cognitive screening instrument of attention and orientation, memory, fluency, language, and visuospatial abilities (Addenbrooke's Cognitive Examination, ACE–R; Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006) with scores ranging from 85.00-93.00 and mean score of 89.00 (*SD*=2.40). In addition, a Mini-Mental State Examination (MMSE; Folstein et al., 1975) score was derived from the ACE-R and the stroke patients, and healthy controls did not significantly differ, *t* (13) = -2.08, *p* = .06.

Stroke patients and their carers were also asked to fill in the Frontal Systems Behaviour Scale (FrSBE; Grace & Malloy, 2002) as a measure of three behavioural syndromes: apathy, disinhibition and executive dysfunction. In addition, six out of eight stroke patients were administered the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996) to predict everyday problems associated with dysexecutive syndrome. One patient was unable to complete the BADS due to hemiplagia, and the other due to tiredness.

Table 5.3. Means and standard deviations for the patients and healthy controls' characteristics.

	Healthy Control (n = 7)		Stroke Patients (n = 8)	
	M	*SD*	*M*	*SD*
Age	60.29	10.13	63.50	13.78
Years of education	14.00	3.37	11.75	3.81
WTAR	109.71	7.83	102.00	13.17
MMSE	29.43	0.79	28.50	0.93
DSST	49.71	10.92	36.57	7.18

Note: WTAR = Wechsler Test of Adult Reading; MMSE = Mini Mental State Examination; DSST = Digit Symbol Substitution Test

Materials

Assessment of behaviour change

Frontal Systems Behaviour Scale (FrSBe; Grace & Malloy, 2002). This test is formerly known as the Frontal Lobe Personality Scale (FLOPS: Grace, Stout, & Malloy, 1999). The FrSBe is a 46-item behaviour rating scale which is designed to measure behaviour associated with damage to the frontal systems of the brain (see Appendix 12). According to the manual, the FrSBe assesses adult behaviour associated with frontal systems damaged before and after injury. It is comprised of two rating forms: a self-rating form to be completed by the patient and a family rating form to be completed by a person in regular contact with the patient; this could be a spouse, child, relative or significant other.

Each form yields a total score and scores for three sub-scales measuring apathy, e.g. 'Have difficulty starting an activity, lack initiative, motivation';

disinhibition, e.g. ‘I am easily angered or irritated; I have emotional outbursts without good reason’ and executive dysfunction, e.g. “Show poor judgment, poor problem solver” (see Table 5.1). Participants responded to each statement on a Likert-type scale (1=almost never, 2=seldom, 3=sometimes, 4=frequently, 5=always) and provided two ratings for each item; one relating to the presence or absence of each behaviour before stroke, and a one relating to the presence or absence of each behaviour since stroke. This means that behaviour change can be indexed by comparing T scores based on normative data of the ratings of prior and current patient behaviour (Malloy & Grace, 2005). Scores below 59 indicate no functional impairment, whereas scores ranging from 60 to 64 reflect borderline impairment. Scores of 65 and over reflect clinically significant impairment.

The Behavioural Assessment of the Dysexecutive Syndrome (BADS) is a test battery predicting everyday problems arising from the Dysexecutive Syndrome (DES) previously known as ‘frontal lobe syndrome’ (Wilson et al., 1996). The test composed of six subtests: Rule Shift Card Test, Action Program Test, Key Search Test, Temporal Judgment Test, Zoo Map Test, Modified Six Elements Test and Dysexecutive Questionnaire (DEX) (see BADS manual for test description; Wilson et al., 1996). The method of scoring for each test ranged from 0-4, where higher scores indicate better performance. An overall profile score for each test is added together to form an individual profile score that can range from 0 to 24. The profile score is then converted into a standardised score with the following age sensitive classification: any score below 69 indicates impairment; scores ranging from 70-79 indicate borderline impairment; 80-89: low average; 90-109: average; 110-119: high average; 120-129: superior; 130-139: very superior.

During assessment it was found that changing the test instructions in one of the tasks (i.e. the key search) from the first to the third person perspective could influence patient performance (see Appendix 13 for further information).

Cognitive Screening

Addenbrookes Cognitive Examination – Revised (ACE-R; Mioshi et al., 2006). The ACE-R is a brief, sensitive and specific test to detect cognitive dysfunction. The ACE-R provides five sub-scores on cognitive domains such as attention/orientation (18 points), memory (26 points), fluency (14 points), language (26 points) and visuospatial (16 points). The maximum score is 100 points, composed by the addition of all the domains. A score of less than 80 indicates significant cognitive impairment. The MMSE, WTAR and DSS tests used in the current study are described in Experiment 1.

Experimental Tasks

Unimodal Facial Emotion Identification. The ability to recognise emotional expressions from faces was tested using the Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002). Sixty black and white photographs of faces displaying one of the six basic emotions (happiness, surprise, fear, sadness, disgust and anger) were shown, one at a time, in the middle of a computer screen. Participants were instructed to choose which of the six labels best described the emotion displayed on each face. Photographs were presented in a pseudorandom order, and 10 examples of each emotion were displayed. The faces were shown for a period of 5 seconds each, but participants could take as long as they wished to decide on the emotion and no feedback was given about the accuracy of a participant's choices. The task started with 6 practice trials. The dependent variable was percentage accuracy for each emotion (see Appendix 2 for test instructions).

Unimodal Prosodic Emotion Identification. The ability of stroke patients to process emotional information from voices was examined. Auditory affective stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA) and were presented through headphones. The prosodic emotional stimuli were taken from the Montreal Affective Voices (Belin et al., 2008) which take the form of short non-linguistic interjections of the vowel /a/. The set contained a series of nonverbal affective emotions (anger, disgust, fear, happiness, sadness, and surprise). In the current paradigm the prosodic stimuli were presented for no longer than 450 ms. Four female voices and four male voices were used, all portraying an example of each emotion. Therefore, each vocal emotion was presented 8 times giving a total of 48 trials. Prior to performing the task, participants performed 6 practice trials. For each trial, participants decided whether the interjection was most like happiness, sadness, surprise, fear, disgust or anger by pressing one of 6 labelled buttons corresponding to each of the emotions. No feedback was given. Participants could take as long as they wished to decide on the emotion. The stimuli were presented in a random order. The dependent variable was percentage accuracy (see Appendix 3 for test instructions).

Cross-modal Emotion Matching. For this auditory and visual cross-modal paradigm, the series of faces adopted from Facial Expressions of Emotion: Stimuli and Test (FEEST*;* Young et al., 2002) and the prosodic emotional stimuli from

Montreal Affective Voices (Belin et al., 2008) were used as described above. Participants were presented with an emotional expression on a face at the same time as a prosodic emotional interjection. Emotional faces (2 male and 2 female) taken from Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002) were paired with actors' voices (2 male and 2 female) from the Montreal Affective Voices (Belin et al., 2008) in a way that a particular face always appeared with same gender corresponding prosodic expression.

In congruent trials, 6 facial emotions (anger, fear, disgust, sadness, happiness and surprise) were paired with matching corresponding prosodic expressions, for instance 'happy'-happy, 'sad'-sad. Face-voice pairings for each of the six emotions were repeated 4 times, giving a total of 24 congruent trials. In audio-visual incongruent trials, the same 6 facial emotions were presented 4 times but with a nonmatching prosodic expression e.g. 'happy'-sad, giving again a total of 24 incongruent trials. In incongruent trials, the facial emotion-prosodic expression pairings were different each time. Each negative emotion presented on the face (fear, sadness, disgust and anger) was paired once with happiness and once with surprise (in other words once each with the two positive emotions) and paired in the remaining two trials with two of the other negative emotions (randomly allocated). Positive emotions presented on the face (happiness and surprise) were paired once with the four negative emotions (disgust, sadness, anger and fear) presented in the voice. Each emotional voice in the incongruent face-voice pairings was presented 4 times across all the trials. Following the methods of previous experiments in this field of multisensory congruence detection, e.g. Laurienti et al. (2004) we also included some control trials. In these control trials, 6 facial emotions (anger, fear, disgust, sadness, happiness and surprise) were presented without a prosodic stimulus and were repeated 4 times, giving a total of 24 control trials.

In order to be comfortable with the task participants performed 6 practice trials. The stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, PA, USA). The visual stimuli were presented in the middle of a computer screen and the auditory stimuli were presented through headphones. Each trial started with a 2s fixation cross in the centre of the screen. The audio-visual stimuli were then presented in synchrony, where the visual stimuli were presented for a maximum of 1000 ms and the auditory stimuli was presented for no longer than 450 ms. Participants were asked to attend to the emotional expression on the face and identify whether the audio-visual stimuli were congruent, incongruent or face-only control trials by pressing one of 3 possible response buttons, responding as quickly and accurately as possible. The dependent variable was the percentage accuracy for each condition. The order of the stimuli was randomised (see Appendix 4 for test instructions).

Procedure

Stroke patients were recruited through the Stroke Unit at the Royal Infirmary of Edinburgh. During their inpatient stay, patients who were considered clinically capable of taking part in the study were identified. After describing the purpose of the project to the patient and what would be required of them, they decided whether to take part. The researcher attended the hospital weekly to recruit patients. However, many of the patients on the Acute Stroke Unit were not suitable for testing due to a large degree of impairment and did not meet our selection criteria (see the

Participants section). While in total 20 patients agreed to take part in the research study on the ward, only eight were willing to participate when they returned home. A group of controls matched in age, gender and education was recruited through a participation database held at the University of Edinburgh.

All patients and healthy controls first performed the screening tests described in Chapter 2 (Experiment 1) to rule out cognitive and perceptual problems: Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983) and the Florida Affective Battery: Subtests 6 & 7 (FAB; Bowers et al., 1991). The Wechsler Test of Adult Reading (WTAR UK; Wechsler, 2001) was administered to provide an estimate of premorbid intelligence.

In addition, all patients were administered the Frontal Systems Behaviour Scale (FrSBE; Grace & Malloy, 2002), the Addenbrooke's Cognitive Examination Revised (ACE–R; Mioshi et al., 2006) and the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996). Finally, both patients and healthy controls performed the three experimental tasks (facial, prosodic and cross-modal emotion tasks); the order of these tasks was counterbalanced across participants. In each of the tasks, the sound level was adjusted to be comfortable, and participants were seated approximately 50 cm from the visual display.

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. Informed consent was obtained for all research volunteers according to the Declaration of Helsinki and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee. Ethical approval was also obtained from the Lothian Local Research Ethics Committee and the researcher had an honorary contract with NHS Lothian for the Royal Infirmary of Edinburgh.

Results

The main aim of the current experiment was to examine whether a task assessing the integration of cross-modal emotional information might be more sensitive to stroke and social behaviour problems than traditional unimodal measures of emotion perception. It was also predicted that patients who show behavioural changes on FrSBe will display more difficulties integrating multisensory information, than patients without behavioural change. The descriptive information showing stroke hemispheric localisation and the performance of each individual patient on each task, are presented in Table 5.4.

Table 5.4. Mean percentage accuracy of each individual patient performing the unimodal and cross-modal tasks with a score of behavioural change post stroke (FrSBe) and hemispheric localisation of the lesion.

					Percentage Correct											
Patient	Stroke LH/RH	FreSBe Self Report	Cross-Modal Cong	Cross-Modal Incong	Angry Faces	Happy Faces	Fear Faces	Sad Faces	Disgust Faces	Sur-prise Faces	Angry Voices	Happy Voices	Fear Voices	Sad Voices	Disgust Voices	Sur-prise Voices
AMc	RH	46	79	71	70	100	60	70	20	70	75	75	38	63	38	38
CW	RH	78	25	75	80	100	10	80	60	100	50	100	38	100	50	63
JS	RH	94	17	58	40	100	60	60	30	70	25	100	38	75	63	63
FH	RH	69	29	79	30	90	80	60	40	90	63	100	50	100	63	50
SA	RH/LH	58	92	42	60	100	60	70	90	90	38	63	00	100	63	50
JW	LH	77	67	54	70	100	10	100	100	100	25	100	50	100	63	63
AM	n/a	65	92	54	50	100	30	100	80	100	63	100	38	75	75	63
JH	LH	56	92	67	40	100	90	100	90	80	50	88	75	100	75	50

Note: RH =right hemisphere, LH =left hemisphere, RH/RL =bilateral, n/a= not available

FrSBe

Observation of the data yielded from the FrSBe measures reveals that six out of 8 stroke patients reported impairments in each of the three sub-scales, i.e. apathy, disinhibition and executive dysfunction (see Table 5.5).

Table 5.5. T- scores reflecting behavioural change on the FrSBe subscales (apathy, disinhibition and executive functioning) on the self and family rating forms before and after stroke.

Patient	Rating Form FrSBe	Apathy Before	Apathy After	Disinhibition Before	Disinhibition After	Executive Dysfunction Before	Executive Dysfunction After	Total Score Before	Total Score After
AMc	Self	45	45	31	31	52	52	43	43
	Family	48	48	40	40	49	49	46	46
CW	Self	56	67 **C**	45	53	76 **C**	91 **C**	63 **B**	78 **C**
	Family	52	59	43	49	70 **B**	79 **C**	58	67 **C**
JS	Self	65 **C**	84 **C**	65 **C**	74 **C**	86 **C**	95 **C**	79 **C**	94 **C**
	Family	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
FH	Self	46	66 **C**	59	71 **C**	44	61 **B**	49	69 **C**
	Family	66 **C**	86 **C**	69 **C**	80 **C**	77 **C**	99 **C**	75 **C**	101**C**
SA	Self	77 **C**	77 **C**	34	39	52	52	56	58
	Family	65 **C**	110**C**	37	61 **B**	63 **B**	102 **C**	57	106 **C**
JW	Self	55	69 **C**	50	63 **B**	63 **B**	80 **C**	59	77 **C**
	Family	66 **C**	72 **C**	55	58	74 **C**	83 **C**	70 **C**	78 **C**
AM	Self	60 **B**	60 **B**	61 **B**	61 **B**	65 **C**	65 **C**	65 **C**	65 **C**
	Family	71 **C**	71 **C**	46	46	63 **B**	63 **B**	64 **B**	64 **B**
JH	Self	50	56	51	53	56	56	53	56
	Family	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Note: **C** = clinical impairment, **B** = borderline impairment, n/a = not available

In the current study, the FrSBe questionnaire indicated that six out of 8 patients display some degree of behavioural change following stroke. Two of the family rating profile forms could not be obtained, and some forms were filled in by people not related to the patient, e.g. neighbour or displaying some degree of aggressive behaviour or negativity towards the patient. Therefore, for consistency, only the self-rating profile forms will be used. Please note as only two patients show no changes in behaviour, in further analysis only patients with behavioural change and healthy controls will be compared. It was reported that patients who display behavioural changes following stroke perform differently on social cognition tasks from patients without behavioural change (e.g. Hornak et al., 1996). Due to the small sample it was not possible to compare the performance of patients who show changes in social behaviour with patients who do not display such change. Therefore, the patients who display changes in social behaviour will be compared with healthy age and IQ matched controls.

BADS

The results of the BADS with standardized scores ranging from 49.00 to 108.00 (*M*=81.67, *SD*=24.34) revealed that two patients out of six showed clinical impairment associated with dysexecutive syndrome (with scores of 49 and 58), and one was borderline (with score 78). The other three patients performed within the average range (with scores of 93, 104 and 108).

***Unimodal Facial Emotion Identification*.**

A mixed 2 (group: patients with behavioural change and healthy control) x 6 (emotions: anger, fear, disgust, sadness, happiness and surprise) ANOVA was conducted on percentage correct identifications of facial expressions of emotion; see Figure 5.1 for descriptive information. There was a main effect of emotion, F (5, 55) = 9.53, $p < .001$, $\eta_p^2 = .46$. Pair wise comparisons with Bonferroni adjustment revealed that the emotion happiness was significantly better identified than anger ($p < .001$); fear, ($p = .002$); and disgust ($p = .032$). In contrast, the emotion anger was recognized more poorly than surprise ($p = .007$). There was no effect main effect of group, F (1, 11) = 1.25, $p = .29$, $\eta_p^2 = .10$ where stroke patients performed as well as healthy controls. The interaction between group and emotions was also not significant F (5, 55) = 2.05, $p = .09$, $\eta_p^2 = .16$.

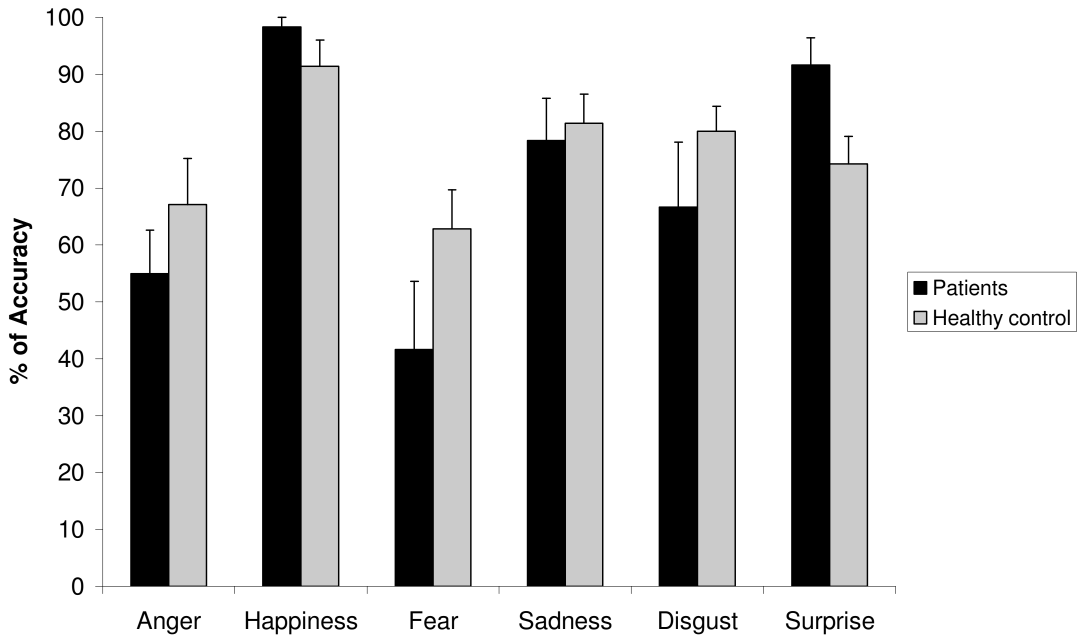

Figure 5.1. Mean percentage accuracy and standard error of the mean for patients with behavioural change and healthy controls performing the facial emotion identification task

***Unimodal Prosodic Emotion Identification*.**

Descriptive information for this task is shown in Figure 5.2. A 2 (group: patients with behavioural change and healthy control) x 6 (emotions: anger, fear, disgust, sadness, happiness and surprise) ANOVA was conducted on the percentage of correct responses. There was a main effect of emotion F (5, 55) = 18.58, p < .001, η_p^2 = .63. Results of pair wise comparisons with Bonferroni adjustment suggest that the vocal emotion happiness was significantly easier to identify than anger (p < .001); fear (p < .001); disgust (p = .002), and surprise (p = .002). Among the negative prosodic emotions, sadness was significantly easier to recognize than anger (p < .001); fear (p = .01) and surprise (p=.02). There was no main effect of group, F (2, 11) = .15, p= .70, η_p^2 = .01, thus suggesting that stroke patients with behavioural change post-stroke performed as well as healthy controls. The interaction between group and emotion was not significant, F (5, 55) = 1.40, p = .24, η_p^2 = .11.

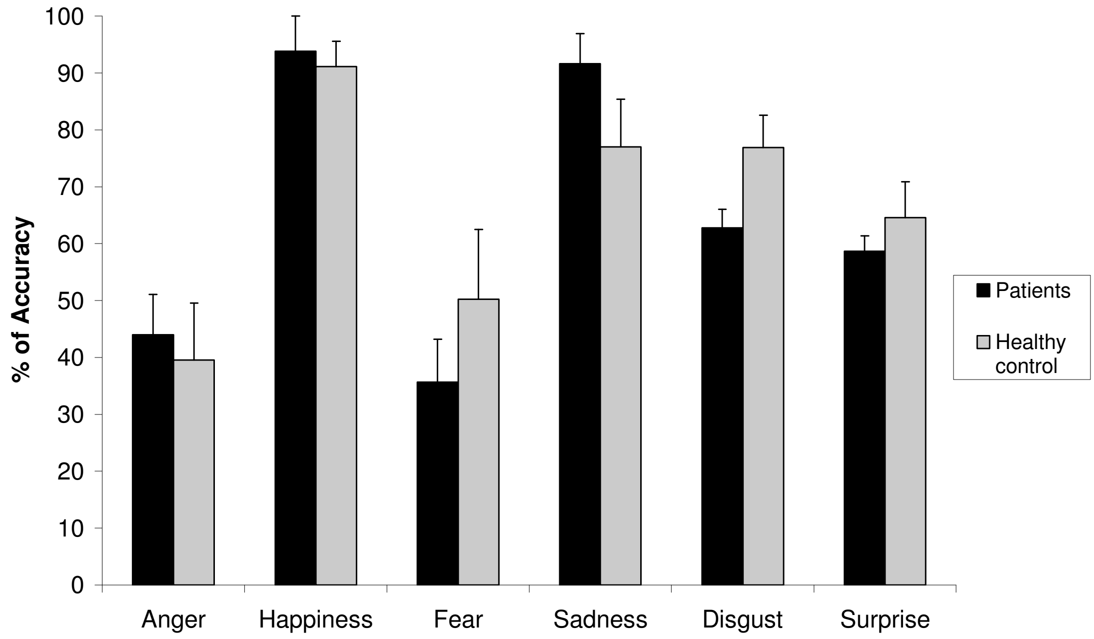

Figure 5.2. Mean percentage accuracy and standard error of the mean for patients with behavioural change and healthy controls performing the prosodic emotion identification task.

Cross-modal Emotion Matching.

The percentage of correct responses for each group (patients and healthy control) in each of the conditions (congruent, incongruent and control) are illustrated in Figure 5.3. A mixed 2 (group) x 3 (condition) ANOVA was conducted on the percentage of correct responses.

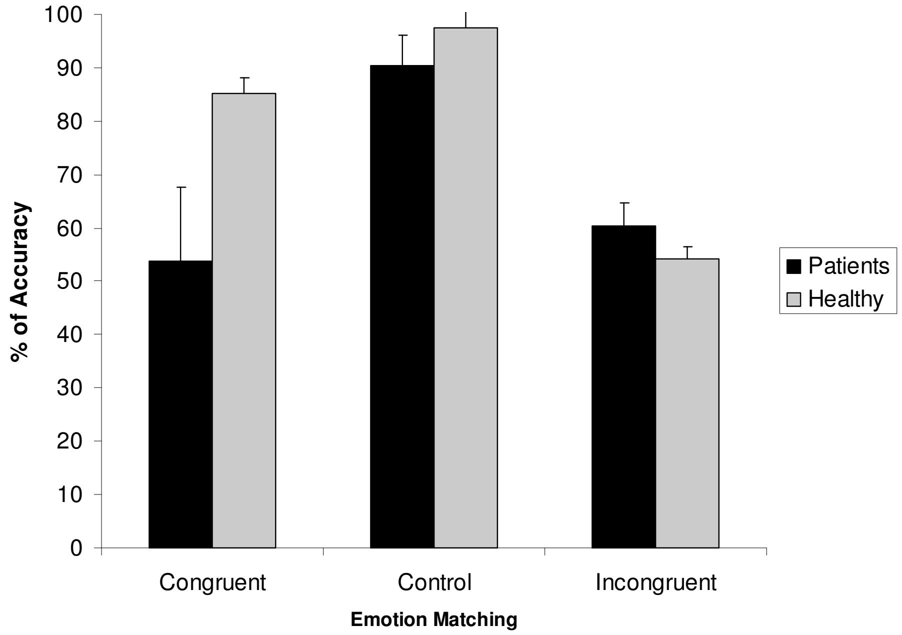

Figure 5.3. Mean percentage accuracy and standard error of the mean for patients with behavioural change and healthy controls performing the cross-modal emotion matching task.

The main effect of group approached significance, F (1, 11) = 4.46, p=.058, η_p^2 = .29 with patients performing more poorly than healthy control. The results also showed that there was a significant main effect of condition, F (2, 22) = 15.31, p < .001, η_p^2 = .58 and pair wise comparisons revealed that the control condition was more accurately performed than the incongruent (p<.001) and congruent (p=.001) conditions. The interaction between group and condition was also significant, F (2, 22) = 4.02, p =.03, η_p^2 = .27. Independent sample t-tests revealed that patients and healthy controls did not significantly differ in matching faces to voices in either the incongruent or control condition. However, in the congruent condition healthy controls performed significantly better than patients, t (11) = -2.38, p = .04.

To ensure that older adults did not simply perform well on the congruent condition due to a bias to press the congruent response button when performing the task, we measured the response bias (criterion β) and sensitivity (d') using Signal Detection Theory (for a review see Swets, 1996) on the congruent and incongruent trials. Patients and controls did not significantly differ in terms of response bias (M = 1.67, SD = .78; M =1.87, SD = .58, respectively), t (13) = -.55, p = .59, and therefore there was no bias in responding to the stimuli. There was also no significant difference between patients and controls in the sensitivity parameter d' (M =.74, SD = .88; M = 1.20, SD = .48, respectively), t (13) = -2.35, p = .24, suggesting that both groups were equally sensitive in discriminating the difference between congruent and incongruent stimuli than older adults.

Correlations

A Pearson correlation conducted on the FrSBe and cross-modal task performance of 8 stroke patients revealed that participants who scored higher in terms of behavioural change performed more poorly in the congruent cross-modal matching task than participants who had lower scores on the FrSBe but the same was not found in the incongruent cross-modal condition .These results might suggest that patients who show behavioural change might especially have difficulties to combine congruent cross-modal information (see Table 5.6).

Table 5.6. Pearson correlations between FrSBe scores and performance on the cross-modal congruent and incongruent tasks in stroke patients (N=8).

	Total Frsbe	(A)	(D)	(E)	Congruent	Incongruent	Digit Symbol	BADS
Total FrSBe	-							
(A)	**.79***	-						
(D)	**.81***	.54	-					
(E)	**.91****	.57	.60	-				
Congruent	**-.75***	-.48	-.60	**-.75***	-			
Incongruent	-.64	-.46	.11	.07	-.50	-		
Digit Symbol	-.44	.01	-.33	-.60	**.77***	-.69†	-	
BADS	-.76†	-.33	-.44	**-.94****	.57	-.11	.58	-

Note: A=Apathy, D=Disinhibition, E=Executive Functioning, FrSBe=Frontal System Behavior Scale, BADS=Behavioral Assessment of the Dysexecutive Syndrome.

Significant correlations: * $p < .05$, and ** $p<.01$. Any trends towards significance are presented with a cross (†).

The results suggest that poorer integration of congruent cross-modal information was associated with lower scores on the FrSBe Executive Functioning behavioural syndrome after stroke. Further analysis using Pearson correlations between performance on the unimodal facial and prosodic emotion identification tasks and performance on the behavioural change questionnaire are shown in Table 5.7

Table 5.7. Pearson correlations between performance on the unimodal facial and prosodic emotion identification tasks and behavioural change questionnaire (FrSBe).

	FrSBe	(C)	(I)	Anger (V)	Happy (V)	Fear (V)	Sad (V)	Dis-gust (V)	Surprise (V)	Anger (F)	Happy (F)	Fear (F)	Sad (F)	Dis-gust (F)
FrSBe	-													
(C)	**-.75***	-												
(I)	-.06	-.49	-											
Angry (V)	-.70	.24	.55	-										
Happy (V)	.69	-.58	.39	-.15	-									
Fear (V)	.03	-.07	.57	.13	.56	-								
Sad (V)	.18	-.88	.01	-.38	.08	.11	-							
Disgust (V)	.23	.27	-.39	-.31	.28	.27	.35	-						
Surprise (V)	**.83****	-.37	-.26	-.60	.71	.03	.22	.44	-					
Angry (F)	-.13	.11	-.10	-.03	-.21	-.33	-.03	-.62	.07	-				
Happy (F)	-.04	.40	-.53	-.32	-.26	-.18	-.28	-.06	.21	.57	-			
Fear (F)	-.37	.13	.19	.26	-.36	.22	-.04	.20	-.65	**-.75***	-.40	-		
Sad (F)	-.16	.59	-.24	-.06	.21	.43	.19	.48	.32	.23	.46	-.37	-	
Disgust (F)	-.04	.56	-.56	-.40	-.06	.03	.62	.63	.36	.14	.31	-.28	**.76***	-
Surprise (F)	.18	.08	-.15	-.09	.34	-.10	.56	.30	.56	.31	-.08	-.66	.50	.64

Note:FrSBe=Frontal System Behavioural Scale, C=Congruent, I=Incongruent, V=Voices, F=Faces. Significant correlations: * $p < .05$; ** p<.01.

Discussion

The main aim of the current study was to investigate whether a task assessing the integration of cross-modal emotional information might be more sensitive to stroke and social behaviour problems than traditional unimodal measures of emotion perception. Analysis revealed that patients who displayed behavioural change post stroke performed as well as matched (age, gender, IQ and years of education) healthy controls when identifying emotion identification from faces and voices only. In a recent study by Milders et al. (2008) assessing changes in social behaviour in 33 traumatic brain injury patients (TBI), and its association with emotion recognition from faces (Ekman & Friesen, 1976) and voices (FAB: Bowers et al., 1998), it was found that TBI patients performed poorer on emotion recognition in only one modality (faces and voices), contrary to findings in this experiment. One of the reasons of why stroke patients in the current experiment performed as well as controls on unimodal emotion recognition might be they have a smaller degree of impairment than the TBI patients in the study of Milders et al. (2008).

Nevertheless, the further results from study of Milders et al. (2008) reported that there is no significant relationship between changes in social behaviour following traumatic brain injury and emotion recognition unimodally which are in line with findings reported in this experiment. Despite some evidence suggesting that certain changes in social behaviour such as the ability to make appropriate communication are correlated with emotion recognition (e.g. Hornak et al., 1996; Pettersen, 1991), the association between these variables was weak and diminishes if the alpha level is adjusted when correcting for multiple comparisons (Milders et al., 2008).

In this current experiment, it was found that the behavioural changes reported in patients post-stroke were not associated with unimodal emotion recognition deficits. However, the results showed that patients who reported changes in social behaviour on self-reporting questionnaires performed poorer when detecting cross-modal congruence of emotions than healthy control. In cross-modal research, congruence is defined as an intuitive match between two sensory modalities and in social situations between two sources of emotional information. Problems in identifying whether cross-modal stimuli are congruent may cause numerous problems in social situations. For instance, failure to notice congruence can produce a failure to modify a person's behaviour in response to changing social situations. The social context may vary according to the situation but the main goal is to manage interactions that require the adjustment of one's own behaviour to the intentions of others. This requires numerous higher and lower order skills such as the identification of the emotions of others and the successful combination of multisensory signals in order to form a unified percept.

Our previous research has shown that older adults are better than younger adults at identifying emotions when the emotional cues are presented congruently both visually (in faces) and aurally (in voices). Yet, stroke survivors with behavioural change have shown the opposite pattern and tend to perform poorer when asked to match cross-modal congruent sources of information. The study of Laurienti et al. (2004) reported enhanced brain activity in the anterior cingulate gyrus and medial prefrontal cortices during the congruent condition. Therefore, it would be interesting to investigate in the future if specific damage to the frontal lobes might impair congruent cross-modal integration. It was not possible to address this in the current study due to the small number of patients who were recruited for the study on the basis of their first ischemic or haemorrhagic stroke which was confirmed by a CT scan and not on the basis of specific stroke localisation. Also, as in case of patient AM, patients might be diagnosed with stroke by the consultant neurologist however stroke might not be seen on CT scan. Reasons for this discrepancy between neurological consultation and CT scan diagnosis include CT scans being performed during the onset of stroke when any abnormalities in the brain will not be seen until several hours after stroke onset, the stroke could be too small to appear on the scan, or the affected brain area might be located in the brainstem or cerebellum where it is difficult to obtain a good CT scan image.

In the incongruent cross-modal condition, the stroke patients (mean age = 67 years) performed as well as age matched healthy controls on matching incongruent cross-modal information and there was no significant association between changes in social behaviour and the detection of incongruence. However, it is important to highlight that generally healthy older adults tend to perform significantly poorer than younger adults on these tasks (see Chapter 2). Hence, our stroke patients did not show further decline in incongruence matching as those related to age. Nevertheless, it would be useful to investigate in a much larger sample whether the lack of a significant difference between stroke patients and healthy controls on incongruent emotion matching is driven by age related changes. It was suggested that poorer understanding of cross-modal conflicting emotional cues in older adults may reflect age decline in cognitive abilities tapping the DLPFC (Hunter et al., 2010; Chapter 2), given the evidence for the role of DLPFC in incongruent cross-modal matching task (Plaza et al., 2008). Hence, it would be interesting to compare how a younger group of stroke patients (below 60 years old) and their control group would perform in the detection of cross-modal incongruence.

The other aim of this study was to investigate whether multisensory integration of emotional information is one of the underlying deficits in patients who report changes in their social and emotional processing. It was found that patients who show changes in social behaviour following stroke are more likely to show problems in integrating cross-modal congruent stimuli. The results of this study also show that changes in social behaviour are frequently reported post-stroke as 6 out of 8 patients displayed such changes. This is in line with studies that found that behavioural changes are a common consequence of stroke (e.g. Bogousslavsky, 2003; Stone et al., 2004, Anderson et al., 1995). Further results also show that patients who performed poorer on BADS were more likely to display changes in social behaviour on FrSBe. Moreover, it was also found that poorer speed of processing (as assessed by the DSST) could also contribute to further difficulties in integration of audio-visual information, in line with previous literature (Madigan, DeLuca, Diamond, Tramontano, & Averill, 2000).

In the current study, only a self reported questionnaire was used to look at behavioural changes. One of the reasons for this, it was observed on some occasions the patient’s partner displayed a negative attitude towards the patient, for instance refusing to bring a cup of coffee to the patient, or saying negative things about patients without caring that this might harm a patient's feelings. On one occasion during a testing session the wife of the patient said in front of the patient and myself, she filled in the questionnaire the way she hopes 'will lock her husband in a loony bin', greatly upsetting the patient. This example suggests that stroke in a close partner or relative can also have a considerable impact on carers and may also affect their judgment of the patient's behaviour. For example, Anderson et al. (1995) found that those caring for patients with behavioural changes after stroke had significant higher ratings on anxiety and depression scales than those caring for patients with physical disabilities. Similarly, Stone et al. (2004) report two further studies that found that changes in social behaviour in patients could act as a predictor of carer depression (Draper, Poulos, Cole, Poulos, & Ehrlich, 1992; Kinney Kinney, Stephens, Franks, & Norris, 1995).

However, there is also a potential problem in using self reports. For instance, it has been reported that stroke patients who suffer with anosognosia could fail to recognize their own disease or impairment (e.g. Weinstein & Kahn, 1955; Damasio, 1999; Blakeslee & Ramachandran, 1999). For instance, Damasio describes patient DJ with prominent left sided hemiplagia. DJ was unable to move her hand; however she would insist that she was completely healthy. When DJ was asked to move her hand, she would reply that her arm 'doesn't move much by itself' still denying her impairment (Damasio, 1999, p.211). In the current study, all patients were able to recognize and deal with their illness.

One of the limitations of this pilot study is the lack of information about exact localisation of the stroke and small sample size. Small sample size may explain the null findings for unimodal emotion perception. However, despite the lack of power there was still a clear and interesting pattern that cross-modal matching was both sensitive to stroke and correlated with behavioural problems. Therefore, important factors to consider in future research are looking at the exact stroke localisation with relation to social changes post-stroke and cross-modal integration. In addition, it is important to assess the impact that these changes in behaviour post-stroke has on stroke survivors in terms of their quality of life and relationships with their carers, and carers themselves. Finally, considering that stroke patients have complex emotional needs due to large changes in their life pattern, frustration, lack of rehabilitation, family complaints, mobility problems, etc. it would be worth investigating how these factors further contribute to changes in behaviour post stroke.

Conclusion

In conclusion it was found that stroke patients who show changes in social behaviour are more likely to display changes in integrating cross-modal social information. Also, cross-modal integration of emotion is more sensitive to stroke-related behavioural problems than simple measures of emotion perception.

Chapter 6: Effects of Age and Type of Task on Theory of Mind (ToM) Performance

Introduction

The aim of this chapter is to examine effects of age and type of task presented in written text and video form on Theory of Mind (ToM) performance. ToM refers to the recognition by a person that other people have mental lives and the use of this information to account for and predict the actions of others (e.g. Premack & Woodruff, 1978). Premack and Woodruff (1978) argue that ToM is essential for comprehension of our own behaviour as well as that of others. Hence, successful interpretation of the mental states may be a fundamental element of successful social interaction and identity.

Due to the complex nature of social exchanges, it has proven challenging to measure ToM experimentally, especially beyond childhood. Developmentally, the most common ToM task is the Sally-Anne False Belief Task (Baron-Cohen, Leslie, & Frith, 1985) where doll figures act out a scenario (see Figure 6.1).

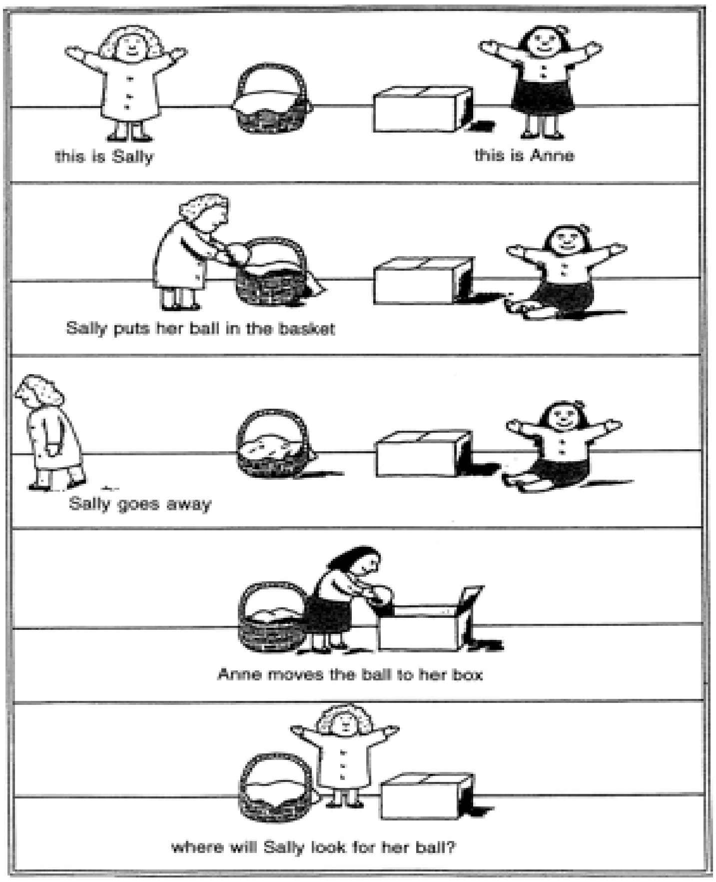

Figure 6.1. The Sally-Anne False Belief Task taken from Baron-Cohen et al. (1985).

However, tasks like 'The Sally-Anne False Belief Task' are less useful in assessing adults because they are too easy. In order to assess the ability to read social cues in the laboratory in adults, researchers have created different types of tasks, with the most common being presented in the form of short stories (e.g. Happé, 1994). Interpreting these stories correctly requires an ability to infer the thoughts and feelings of the protagonist. Generally, each story is followed by verbal questions regarding these intentions. For instance, in the following example adapted from the 'Strange Stories' (Happé, 1994), participants' ability to understanding irony is assessed (see Figure 6.2).

'Ann's mother has spent a long time cooking Ann's favourite meal: fish and chips. But when she brings it in, Ann is watching TV, and she doesn't even look up or say thank you. Ann's mother is cross and says: 'Well that's very nice isn't it! That's what I call politeness!'

Q 1. Is it true what Ann's mother says?

Q 2. Why does Ann's mother say this?

Figure 6.2. Example from the 'Strange Stories' (Happé, 1994).

Although ToM tasks were initially applied to infants and young children, their use has since been broadened to include a wide range of clinical disorders such as autism, traumatic brain injury (TBI), stroke, schizophrenia etc. (e.g. Howlin & Yates, 1990; Baron-Cohen et al., 2001, Channon & Crawford, 2000).

The effects of age on ToM

The effects of age on performance on ToM has been widely investigated, yet the results remain inconclusive as some studies report age effects on ToM performance whereas others show that older adults outperform younger adults. For instance, Happé, Winner, and Brownell (1998) compared the performance of younger (16-30 years old) and older adults (61-80 years old) on two types of stories: one with a ToM component which required a second order reasoning (i.e. what one person thinks about another person's thoughts) and one without a ToM component (the control story) which required the interpretation of physical causality. The study reported that older adults outperformed younger adults on ToM performance, suggesting that older adults might have better ToM abilities than younger adults due to an increase in social intelligence with age (Happé et al., 1998). In contrast older adults were found to perform less well in a study of Maylor et al. (2002) who compared three groups of participants aged 16-29 (young), 60-77 (young-old) and 75-89 (old-old) years. Maylor et al. found the largest age effects on ToM abilities in older adults over 75 years old.

Studies by Happé et al. (1998) and Maylor et al. (2002) both employed similar short story stimuli. However, poorer performance of older adults has also been reported in studies using quite different methods, including cartoon tasks (Saltzman, Strauss, Hunter, & Archibald, 2000) and the ‘mind in the eyes’ task (Phillip et al., 2002). The different patterns of findings might suggest that various ToM measures tap different aspects of social functioning processes and also highlight the importance of ToM assessment on different tasks in the same sample (Saltzman et al., 2000). Sullivan and Ruffman (2004) compared performance of 24 younger (20-46 years old) and 24 older adults (60-82 years old) on three types of ToM task including the Happé et al. (1994) short stories, emotion recognition from static faces based on the Ekman stimuli (1992), and a task where participants had to attribute mental states to characters in a mute video. The results showed that older adults performed less well than younger adults on all tasks. However, the performance on the short stories task was accounted for by older adult’s lower fluid ability, whereas the other two ToM tasks (video and facial emotion recognition) were independent of fluid ability, suggesting independent age-related effects. These studies suggest the different pattern of results in terms of age effects on performance on ToM might be biased by other variables, for instance the type of task involved.

ToM and its association with general cognitive functioning.

As mentioned above, age effects on ToM tasks are in part related to fluid ability. However, older adults also perform less well in general on ToM tasks with high executive demands (German & Hehman, 2006), cognitive load (Keightly et al., 2006) or memory recall (Slessor et al., 2007). For instance, McKinnon and Moscovitch (2007) found that increases in executive demand might account for the poorer performance of older adults on ToM. This study showed that older adults performed less well than younger adults on ToM tasks based on second (but not first) order false belief tasks, i.e., where participants had to consider the thoughts of two different characters simultaneously. A lack of age effects in the first order condition suggests that single-perspective places less impact on executive demands than does the second-order false belief task. This in turn suggests that age primarily affects executive functioning.

Further studies have considered other aspects of cognition, such as intellectual functioning (e.g. Happé et al., 1998) and memory load (Maylor et al., 2002) which are also believed to account for the poorer performance of older adults on ToM tasks. The more recent study of Charlton, Barrick, Markus, and Morris (2009) also reported that performance on ToM tasks in older adults was '*fully mediated by performance intelligence, executive function, and information processing speed and was partially mediated by verbal intelligence*' (p.338). In addition, the study of Charlton et al. (2009) found that white matter integrity as measured by diffusion tensor imaging was associated with performance on ToM tasks. Other neuroimaging studies suggest that age effects on ToM might be also due to deterioration in the frontal and temporal lobes (Greenwood, 2000; West, 1996). Apart from age-related changes in neural and executive functioning there are other factors possibly contributing to different patterns of results on social cognition tasks, including different ToM measures.

ToM and type of task

Age effects on ToM performance could also be influenced by type of task. For instance, Slessor et al. (2007) compared the performance of older and younger adults on different ToM measures. The first task was the short stories task, the second involved recognizing emotions portrayed in the eyes, and the third task was composed of silent video clips where participants had to describe the thoughts and feelings of a person portrayed in a video. It was found that older adults performed poorer when they had to decode social information from static and dynamic visual displays but not from text. Slessor et al. (2007) explained this in terms of older adults' difficulties in the inhibition of irrelevant information and maintaining information in working memory. For instance, in the identification of deceit, sarcasm or lies portrayed through video might require greater demands on executive processes and working memory as multiple aspects of incongruent social information is processed simultaneously, e.g. when identifying sarcasm participants have to attend to one feature (voice prosody) and ignore incongruent lexical meaning and emotions presented on the face (e.g. Sullivan & Ruffman, 2004; Slessor et al., 2007; Hunter et al., 2010).

Research looking at age effects on ToM illustrate that older adults might perform well on some social cognition tasks, but not necessarily on others (e.g. Saltzman et al., 2000). This discrepancy might be not only driven by different ToM measures (see Figure 6.3), but also poorer executive functioning, age related decline in general cognitive functioning or by the ecological validity of the task (e.g. Heavy, Phillips, Baron-Cohen, & Rutter, 2000). Indeed, none of the ToM tasks administered to older adults resemble real-life situations where information is presented simultaneously to both audio-visual channels. Sullivan and Ruffman (2004) used video clips but these were played without the voice. In their study, '*clips were taken from various television programs, news clips and movies. For example, in one video clip the participants saw a young woman sitting on a sofa flicking through a magazine. On the basis of her body posture and facial expression the participant's task was to decide whether she was bored or sad*' (p.6). Hence, age effects were not fully addressed using stimuli which resembles real life social interactions.

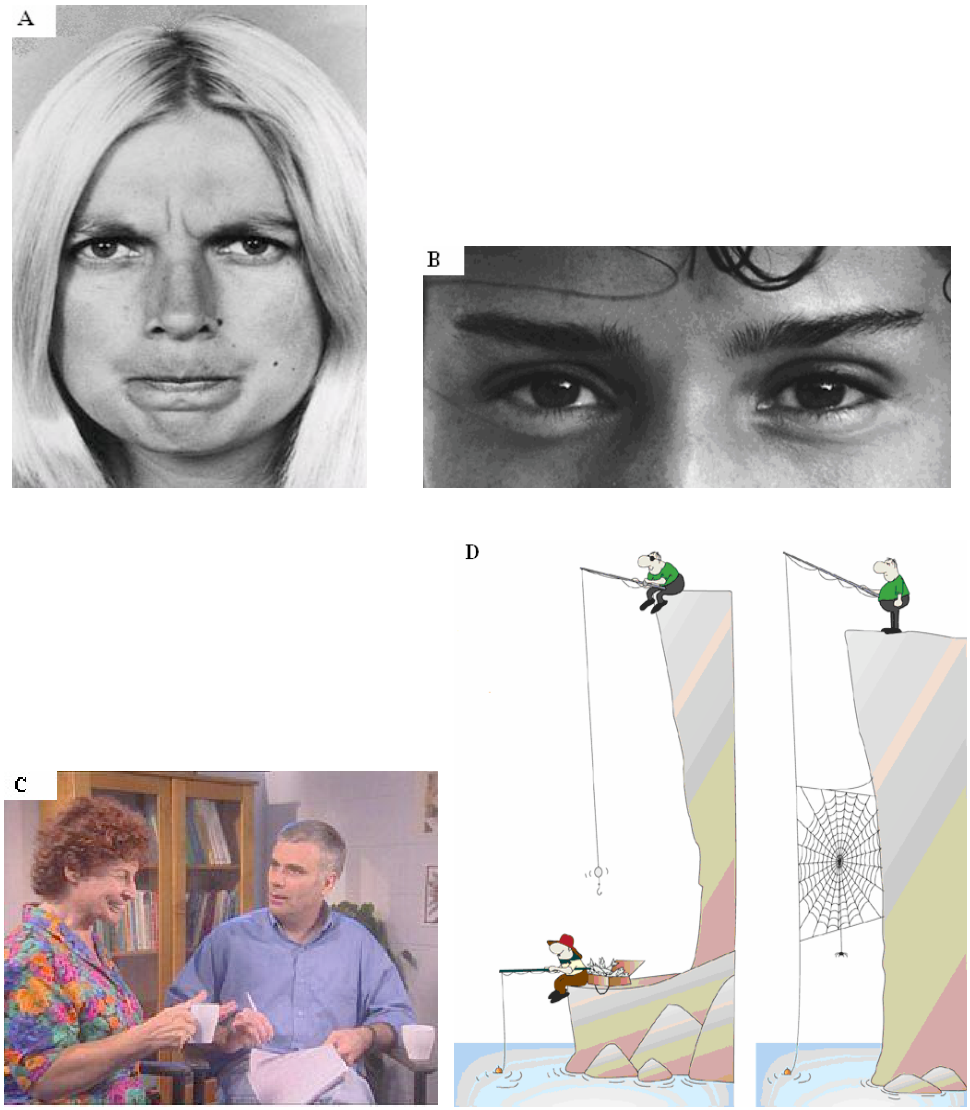

Figure 6.3. shows examples of different types of theory of mind (ToM) stimuli. A. Facial Expressions of Emotion: Stimuli and Test (FEEST; Young et al., 2002) B. The ToM Eye Test (Baron-Cohen et al., 2001) C. TASIT still from a video (McDonald, Flanagan, Rollins & Kinch, (2003) D. The ToM cartoon in the left panel portraits a deceitful man stealing fish. In contrast, the cartoon in the right panel does not involve a ToM (Gallagher et al., 2000; Adolphs, 2003). The above example of tests represents examples presented without words. Similarly to the written ToM tasks, participants are asked to identify the emotion or asked to explain the behaviour, thoughts and feelings of the characters.

ToM tasks and ecological validity

The need for an ecologically valid test to asses ToM was postulated by McDonald, Flanagan, Martin and Saunders (2004) as ‘*assessment of higher-level aspects of social perception requires a vehicle that examines different facets systematically (…) these may include the speaker’s demeanour, the listener’s response, prior knowledge of the true state of affairs, or other contextual information, such as knowledge of customs and culture*’ (p.221). However, as illustrated above, most ToM tasks used in aging studies are contextually and perceptually restricted, i.e. they used static and acted facial expressions, recognition of emotion portrayed only in the eyes, short written and cartoon like stories, or mute videos. It might be argued that each of these tests form only a separate part of a ‘*social perception vehicle’* such as a wheel, engine or breaks etc. In real life situations, this ‘social vehicle’ can be only driven when people are able to successfully combine social, perceptual and contextual cues.

To address this, McDonald, Flanagan and Rollins (2002) created ‘The Awareness of Social Inference Test’ (TASIT) which is similar to real-life social situations. The test is composed of three parts: an emotion evaluation test, a social inference test where the viewer has to identify speaker intentions with no *‘external or additional information*’. In contrast, in the third part of the test the viewer is provided with extra cues while performing the test, e.g. a ‘sarcastic’ actor might reveal his true feelings or thoughts (see the Method section for the test description).

In order to address the need for assessment on more ecologically valid measures in older adults, the TASIT was used. In the current study, it was investigated whether older adults differ in their ability to interpret sarcasm (Part 2) and make interferences about the thoughts and feelings of the speaker in social exchanges involved in more complex sarcasm and lies. Considering the well documented evidence of older adults' poorer performance when identifying deceit presented audio visually (Ekman & O'Sullivan, 1991; Stanley & Blanchards-Fields, 2008), it is expected that older adults will perform more poorly than younger adults in detecting sarcasm and lies. Moreover, difficulties in the detection of lies might be escalated by older adults' difficulties in the detection of incongruence as described in Chapter 2. For instance, when detecting sarcasm or lies, people are presented with visual information which is incongruent compared to the linguistic information and vocal affect cues.

Moreover, this experiment also addresses the gap in the aging literature by investigating the association between decoding sarcasm and lies and the mode of presentation of ToM stimuli in both the written and video form based on the same social interactions. The results from the previous studies described earlier (e.g. Slessor et al., 2007) demonstrate that older adults perform more poorly than younger adults when they have to infer social information from a video, but not written stories. However, it might be that the age effects in performance on video versus written text were driven by other factors, such as different stimuli with different examples of social interactions and an uncontrolled degree of difficulty.

To investigate whether the type of stimuli (written story task and video task) can influence older adults' performance, this experiment incorporates two identical types of tasks both based on identical social interactions. The video task (Part 2, Part 3) is adopted from the TASIT (McDonald et al., 2002) whereas the textual stories which are written in the style of faux pas stories (e.g. Stone et al., 1998) are an exact transcription of the TASIT. In this way, each video scenario has its exact textual equivalent.

Aims of Experiment 8

This experiment is designed to assess the age effects on type of task on theory of mind (ToM) performance. The study compares the performance of younger and older adults on stories and video tasks based on identical social interactions. In line with previous experiments e.g. Slessor et al. (2007), it is expected that social information presented through video will be more sensitive to aging than information presented through text as processing information in a video might require greater demands on executive processes and working memory where multiple aspects of social information is processed simultaneously.

Methods

Participants

Fifty eight healthy volunteers were recruited through the volunteer database held at University of Edinburgh and University of Aberdeen: 28 younger adults (11 men, 17 women) aged between 18-40 with a mean age of 23.14 years (*SD*= 4.20) and 28 older adults (10 men, 18 women) aged between 60-84 with a mean age of 68.93 years (*SD*=7.80). All participants were right handed. They performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult

Intelligence Scale (Wechsler, 1997) to assess speed of processing. Older and younger adults did not significantly differ in years of education t (54) = 1.94, p= .06, or verbal ability, t (54) = 1.91, p = .06 (see Table 6.1 for descriptive information). However, in terms of speed of processing older adults were significantly slower than younger adults, t (54) = 5.41, $p < .001$. Two groups did not differ significantly with regard to gender, χ^2 (1, 56) =2.57, p=.11. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the Wechsler Adult Intelligence Scale-III UK selection criterion (Wechsler, 1997).

Table 6.1. Means and standard deviations for the participant characteristics.

	Younger Adults (n = 28)		Older Adults (n = 28)	
	M	*SD*	*M*	*SD*
Years of full-time education	16.89	2.08	15.07	4.51
WTAR	115.54	4.27	112.86	6.08
DSST	66.36	12.05	48.11	13.17

Note: WTAR = Wechsler Test of Adult Reading; DSST = Digit Symbol Substitution Test

Materials and Procedure

The study compared the performance of younger and older adults on stories and video tasks based on identical social interactions. In the current experiment, The Awareness of Social Inference Test – Part 2 and Part 3 (TASIT; McDonald et al., 2002) was used which is composed of videotaped vignettes of everyday social interactions. Part 2 is called 'The Social Inference-Minimal (SI-M)' test and assesses comprehension of sincere versus simple and paradoxical sarcastic social exchanges.

In Part 3 'Social Inference-Enriched (SI-E)' assesses the ability to perceive lies and sarcasm with more cues to social situations (see below for test description).

Video Task

Part 2 The Social Inference-Minimal Test (SI-M)

The SI-M contains 15 videotaped vignettes ranging in duration from 15-60 seconds. The video scripts represent examples based on everyday situations and interactions, e.g. stories are situated in a naturalistic context such as the office or home. In this part of the task, participants are presented with three different types of social exchanges. The first type is sincere when a speaker means what he or she is saying (5 vignettes). The other two types could be either sarcastic-simple exchange (5 vignettes) or sarcastic-paradoxical (5 vignettes). In a sarcastic–simple type of exchange, sarcasm can be only read in paralinguistic cues, e.g. voice prosody as in the following example (see Figure 6.4).

Michael: Sorry, I can't take that class I said I would take on Friday.

Ruth (sarcastically): That's OK, I know you are busy. Don't worry about it.

In contrast, paradoxical sarcasm could be only understood by people who can detect sarcasm as the dialog does not logically make sense otherwise, e.g.:

Gary: Are you sure you've got your passport?

Keith: (sarcastically) Oh, yes, I tore it up and threw it away.

Gary: Good, that's OK then.

Figure 6.4. Example of sarcastic–simple type of social exchange.

Part 3 The Social Inference Enriched (SI-E)

This part of the task is enriched by extra information about the situation, either by providing the viewer with extra visual cues by means of camera edit or revealing an actor's true feeling in a prologue or epilogue where the recipient of lie/sarcastic remark is not present. The SI-E contains 16 videotaped vignettes that last from 15-60 seconds and looks at the ability to perceive white lies (8 vignettes) and sarcasm (8 vignettes). In each of the scenes, actors say something different to their real thoughts and feelings. In the 'white lie' vignettes, actors try to conceal their true thoughts, e.g. *'Yes, of course, Johnnie has finished his dinner', having just taken away Johnnie's plate which is still full*' (McDonald et al., 2002, p.6). In contrast, in the 'sarcastic' stories, actors deliberately expose their feelings by the use of sarcasm‘, such as ‘saying to a corpulent friend: ‘*No, of course you don’t look fat’* (McDonald et al 2002, p.6).

Written Stories Task

The written stories are based on the videotaped social exchanges in the SI-M (Part 2) and the SI-E (Part 3) of the TASIT. Each vignette used in the video was carefully described taking into consideration the social context of the story, conversation, paralinguistic cues and the actions of the speaker. The story provides as accurate a representation as possible of the video vignettes. Examples of the transcriptions are illustrated below.

Part 2 SI -Minimal

Part 2 is composed of three social exchanges: sincere (see Figure 6.5), involving simple sarcasm (see Figure 6.6).and paradoxical sarcasm (see Figure 6.7), the same as in the video. Examples of the written stories with one of type of social exchange are provided below

'Promotion'

In the following example the speaker (Ruth) means what she is saying.

Michael and Ruth were sitting at their desks at work. Michael said to Ruth, "I wish I knew if the boss thinks I've done well or not this year." Ruth replied, "Hey, everyone knows you've done a great job." "You think so?" Michael asked, "I'd really like to get that promotion." "No doubt about it!" said Ruth smiling, "I wouldn't be surprised if you're made number one before long." "Oh I don't know about that," said Michael. Ruth replied, "Why not? You've shown such dedication, you've worked such long hours, and you've made so many great decisions." "Yeah, well I've tried," admitted Michael. "Without you this company would go broke," said Ruth looking at him, adding frankly, "You're indispensable."

Probe questions (Yes, No, Don't Know):

A. Is Ruth sending Michael up about his chances of a promotion?

B. Is she trying to say he's working really well?

C. Does she think he deserves a promotion?

D. Would she like him to get a promotion?

Figure 6.5. Example of sincere social exchange.

'Going out'

In the simple sarcasm condition, the meaning is incongruent with the speaker's intentions, e.g.:

Ruth was about to go out for the evening, and was putting on her coat when Gary approached. He asked her, "Where are you off to?" "I'm going to Jo's place," she replied. "Don't ask me to come with you!" said Gary chuckling. "Don't worry I won't!" Ruth replied. She asked, "Do I look ok?" "You look terrible!" said Gary. "Thanks!" replied Ruth, "I won't be late." "Ah, so you're coming back?" asked Gary. "Of course," said Ruth. "If you're later than ten, I'll lock the door on you!" Gary warned. "Well, maybe I shouldn't come home at all then!" Ruth answered.

Probe Questions (Yes, No, Don't Know):

A. Is Gary tying to make Ruth feel bad?

B. Is he trying to say that she looks ok?

C. Does she think he's joking with her?

D. Is he angry with her?

Figure 6.6. Example of simple sarcasm.

'Friends House'

This type of sarcasm could only be understood when a person possesses the ability to identify paradoxical sarcasm, e.g.:

Gary was reading the paper when Ruth leaned over the chair to chat to him, saying, "Did you see Janelle's new house? Wasn't it painted the most gorgeous colour?" Gary replied, "Yeah I've no idea why she chose that colour for her walls!" "Mmm, the walls are fabulous," said Ruth "Not nearly as nice as the lovely shade of green on the front door." "Maybe she's colour-blind?" said Gary, and Ruth laughed.

Probe Questions (Yes, No, Don't Know):

A. Is Ruth being complimentary about her friend's house?

B. Is she trying to say that colour scheme is dreadful?

C. Does she think her friend has good taste?

D. Does she disapprove of the colour scheme?

Figure 6.7. Example of paradoxical sarcasm.

Part 3 SI-Enriched

In the enriched part of the task, participants were again assessed on the ability to perceive white lies and sarcasm. However the video provided subjects with 'enriched cues' for social inferences, such as edits to cut-in information such as a shot of a half-empty cup of tea. This provided additional cues as to the true state of the matter. In the written condition, similar additional information was provided (see Figure 6.8).

'Cup of tea'

Gary and Kirsty were in the office. Kirsty had just arrived, and while taking off her jacket, she said, "Oh, I just feel like a cup of tea." Gary replied, "There should be enough in the pot if you'd like to pour yourself some." Kirsty poured some tea, and before the cup was even a quarter full, the teapot was empty. "Is there enough there for a full cup?" asked Gary. "Yeah, There's heaps," replied Kirsty. "If there's not enough I'll make a fresh pot," said Gary. "Oh no, don't put yourself out," replied Kirsty, "There's…there's easily a cupful here." She picked up her cup and started to sip.

Probe Questions (Yes, No, Don't Know):

A. Is Kirsty trying to hide the fact that there's hardly any tea left?

B. Is she trying to say she'd like some more?

C. Does she think there's plenty of tea left?

D. Is she openly annoyed with him?

Figure 6.8. Example of a white lie.

In half of the scenes in Part 3 (same as in the video condition), viewers are shown prologues or epilogues to provide extra cues about the real thoughts and feelings of the speaker. In the following example ‘Boyfriend’, Jane reveals her real thoughts about Annie’s boyfriend in the prologue (see Figure 6.9).

‘Boyfriend’

John and Jane were standing at the dinner table chatting. John turned to Jane and asked her, “What did you think of Annie’s new boyfriend? Isn’t he terrible?” She laughed, “Mmm he’s ghastly. I don’t know what she sees in him. He was such a pain and so boring.” John replied, “I know, I thought I’d fall asleep while he was talking.” “Well I only listened to him for about five minutes,” said Jane, “He was going on and on about some rubbish. I don’t even know what it was, it was so boring.” She laughed again, and Annie came into the room and approached the couple, asking them, “Well, what do you think of the love of my life? Isn’t he great?” Jane nodded, “Mmm. He’s a real catch. I don’t know where you find them.” Annie replied “I think he’s so interesting.” “Yeah!” said Jane, “He’s really… interesting. I could sit and listen to him all day*!*” and she turned to John, smirking.

Probe Questions (Yes, No, Don’t Know):

A. Is Jane trying to reassure Annie that she likes her new boyfriend?

B Is she trying to say she thinks Annie’s boyfriend is great?

C. Does Annie believe Jane likes her new boyfriend?

D. Does Jane dislike Annie’s new boyfriend?

Figure 6.9. Example of enriched sarcastic social exchange.

Procedure

All participants in this experiment performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the Digit Symbol Substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing. In addition, older adults performed the screening tests described in Experiment 1 to rule out cognitive and perceptual problems: the Mini Mental State Examination (MMSE; Folstein et al., 1975), the Benton Facial Recognition: Stimulus and Multiple Choice Pictures (Benton et al., 1983) and the Florida Affective Battery: Subtests 6 & 7 (FAB; Bowers et al., 1991).

Participants were then presented with the TASIT, Part 2 and Part 3. In Part 2 and Part 3, participants were presented with short vignettes based on everyday social interactions. Performance was assessed by asking four questions in order to assess understanding of the emotions, intentions, beliefs, and meanings of the speakers and their exchanges. Questions include asking about intention of the speaker, i.e. what they intend to DO, whether they mean what they are SAYING, what they THINK about the situation as well as what they are FEELING. The correct responses for each item probe (do, saying, think, feel) are marked on the answer sheet given to participants and then transferred into a summary sheet, where a point is awarded for each correctly answered question.

Younger and older adults were assessed on the video task and a stories task which was transcribed from the video stimuli (TASIT, Parts 2 and 3). The scoring procedure for the text and video conditions was identical, giving one point for each correctly identified item. Each Part 2 and Part 3 has separate response sheets and can be presented as either Form A or Form B (there are two alternative videos for each item probe). In the current experiment, each participant performed either one of Part 2 or Part 3 in the video or written condition. As vignettes for Part 2 and 3 are subdivided into Form A and B, each participant received only one of either Form A or B. The presentation of Forms A and B, as well as the order of presentation of Part 2 and Part 3 were counterbalanced across both groups. Participants were presented with one practice example for both written text and video condition.

Participants were told that taking part in the experiment was voluntary and that they could withdraw at any time during the experiment. They were asked to sign a written consent form and were told that any collected data was confidential. They were reimbursed for any expenses incurred for taking part. Informed consent was obtained for all research volunteers and the study was approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee at the University of Edinburgh, and the Psychology Ethics Committee at the University of Aberdeen.

Results

This experiment is designed to assess the age effects on type of task on theory of mind (ToM) performance. The study compares the performance of younger and older adults on stories and video tasks based on identical social interactions. In line with previous experiments e.g. Slessor et al. (2007), it is expected that social information presented through video will be more sensitive to aging than information presented through text as processing information in a video format might require greater demands on executive processes and working memory where multiple aspects of social information is processed simultaneously.

Part 2 Social Inference (Minimal)

A mixed 2 (group: young and healthy older adults) x 2 (condition: written text and video) x 3 (type of exchange: sincere, simple sarcasm, paradoxical sarcasm) ANOVA was conducted on the percentage correct identifications of these exchanges in the video and written conditions; see Table 6.2 for descriptive information. There was a main effect of age F (1, 52) = 8.60, p = .005, η_p^2 =.14 suggesting that older adults performed significantly less well than younger adults in identifying social exchanges. There was also a main effect of condition, F (1, 52) = 13.87, p < .001, η_p^2 =.21 where both groups performed better on the video than the written task. There was also a main effect on type of social exchange F (2, 104) = 8.47, p < .001, η_p^2 =.14 where paradoxical sarcasm was better recognized than sincere exchanges (p=.001) and simple sarcasm (p=.02).

There was no significant evidence for an interaction of age condition (type of task), F (1, 52) = .51, p =.48, η_p^2 =.01. Also the interaction of social exchange and age was not significant, F (2, 104) = .87, p = .42, η_p^2 =.02. The interaction of social exchange and condition was borderline significant, F (2, 104) = 3.01, p = .05, η_p^2 =.05. Further analysis revealed that for both young and old groups found it easier to identify paradoxical social exchanges than sincere, t (29)=-4.14, p<.001 or simple sarcasm, t(29)=-3.54,p=.001 through written text. In contrast, sincere, simple and paradoxical sarcastic social exchanges were equally well identified in video. The three-way interaction between group, type of social exchange and condition was not significant, F (2, 104) = .03, p = .97, η_p^2 = .001.

Table 6.2. Mean accuracy scores and standard deviations for younger and older adults on performance on the types of social inferences in the video and written conditions in Part 2.

	Younger Adults ($n = 28$)		Older Adults ($n = 28$)	
	M	*SD*	*M*	*SD*
Exchange type in video				
Sincere	85.38	15.06	71.54	19.62
Simple Sarcasm	86.15	19.81	80.00	17.44
Paradoxical Sarcasm	91.92	8.79	77.31	21.37
Exchange type in written text				
Sincere	65.00	20.35	57.67	21.37
Simple Sarcasm	68.67	18.66	66.00	19.47
Paradoxical Sarcasm	87.67	13.48	76.67	21.18

Further analysis examined whether there were age related differences on the individual components of exchange types, i.e. intention of the speaker (what they do); literal meaning of the message (what they are saying); knowledge about the situation (what they think) and their emotions (what they are feeling). A mixed 2 (group: healthy younger and older adults) x 2 (condition: written text and video) x 4 (components of social exchange: do, say, think, feel) ANOVA was conducted on the percentage correct identifications of these exchanges in the video and written form (see Table 6.3)

Table 6.3. Mean accuracy scores and standard deviations for younger and older adults' performance on the individual components of social exchanges in the video and written conditions in Part 2.

	Younger Adults (n = 28)		Older Adults (n = 28)	
Individual scores on different exchange types in video	*M*	*SD*	*M*	*SD*
Do	12.92	2.06	12.00	2.08
Say	13.69	1.50	12.08	2.18
Think	13.77	1.23	11.85	1.67
Feel	13.77	1.30	12.46	2.02
Individual scores on different exchange types in written text				
Do	11.87	2.13	10.27	1.83
Say	11.33	1.88	9.67	1.72
Think	11.07	1.34	9.67	1.72
Feel	11.60	1.68	9.87	1.81

There was a main effect of age, F (1, 52) = 14.40, p < .001, η_p^2 =.22 suggesting that older adults performed significantly poorer than younger adults overall. However, both groups performed better in the video than written text condition, F (1, 52) = 28.52, p < .001, η_p^2 =.35. The two way interaction between age group and condition was not significant, F (1, 52) = .06, p =.80, η_p^2 =.001. There was no main effect on identification of individual social exchange components, F (3, 156) = .95, p = .42, η_p^2 =.02. The interaction between age group and individual scores on social exchanges was also not significant, F (3, 156) = .47, p=.70, η_p^2 = .01. Although the interaction between the individual components and condition was significant, F (1,156) = 2.90, p = .04, η_p^2 =.05, after Bonferroni correction for multiple comparisons, none of the pair sample t-tests were significant. The three way interaction between individual components, age group and condition was also not significant, F (1,156) =.71, p = .55, η_p^2 =.01.

Part 3 Social Inference (ENRICHED)

A mixed 2 (group: young and healthy older adults) x 2 (condition: written text and video) x 2 (types of social inference: lies and sarcasm) ANOVA was conducted on the percentage correct identifications for these exchanges; see Table 6.4 for descriptive information. There was a significant main effect of age, F (1, 52) = 10.51, p = .002, η_p^2 =.17 suggesting that older adults performed significantly poorer in identifying lies and sarcasm than younger adults. Also, both groups performed significantly better in video than the written form condition, F (2, 52) = 55.71, p < .001, η_p^2 = .52. However, the interaction between age group and condition was not significant, F (2, 52) = .91, p =.35, η_p^2 = .02. Further analysis showed that there was a main effect of type of social exchange, F (2, 52) = 17.34, p < .001, η_p^2 = .25. Pair wise comparisons revealed that lies were significantly easier to identify than sarcasm. The interaction between group and type of social inferences was not significant, F (2, 52) = .53, p = .47, η_p^2 = .01.

However there was significant interaction between type of social exchange and condition, F (2, 52) = 15.83, p < .001, η_p^2 = .23. The paired sample t-tests revealed that it was significantly easier to identify lies than sarcasm in the written condition, t (25) =4.30, p<.001 (*M*=73.90, *SD*=12.26; *M*=48.75, *SD*=21.20, respectively). There was no significant difference in identifying lies and sarcasm in video, *t* (29) =.22, *p*=.83.

Table 6.4. Mean accuracy scores and standard deviations for younger and older adults on performance on types of social inference in the video and written conditions in Part 3.

	Younger Adults (*n* = 28)		Older Adults (*n* = 28)	
	M	*SD*	*M*	*SD*
Social inferences in video				
Lie	83.39	10.11	76.55	11.29
Sarcasm	86.30	9.17	72.50	16.11
Social inferences in written text				
Lie	76.20	11.65	71.60	12.88
Sarcasm	52.08	11.43	45.41	20.22

Further analysis examined whether there were age related differences on the individual components of exchange types, i.e. the intention of the speaker (what they do); literal meaning of the message (what they are saying); knowledge about the situation (what they think) and their emotions (what they are feeling). A mixed 2 (group: young and healthy older adults) x 2 (condition: written text and video) x 4 (components of social exchange: do, say, think, feel) ANOVA was conducted on the percentage correct identifications of these exchanges in the video and written form (see Table 6.5 for descriptive information)

Table 6.5. Mean accuracy scores and standard deviations for younger and older adults' performance on the individual components of social exchanges in the video and written conditions in Part 3.

	Younger Adults (n = 28)		Older Adults (n = 28)	
Individual scores on different exchange types in video	*M*	*SD*	*M*	*SD*
Do	13.92	1.81	11.80	2.73
Say	13.47	2.23	11.53	2.06
Think	13.40	1.24	12.53	1.41
Feel	14.01	1.44	12.13	1.77
Individual scores on different exchange types in written text				
Do	8.84	1.34	8.23	1.23
Say	8.38	1.44	7.15	1.57
Think	12.61	1.80	11.69	1.89
Feel	9.54	2.90	9.38	1.76

There was a main effect of age, F (1, 52) = 10.27, p = .002, η_p^2 =.16 suggesting that older adults performed significantly poorer on all types of individual components of the social exchanges in both conditions. However, both groups performed better in a video than in written text condition, F (1, 52) = 78.93, p < .001, η_p^2 =.60. The two way interaction between age group and condition was not significant, F (1, 52) = 1.63, p =.21, η_p^2 =.03. There was a main effect on identification of individual social exchange components, F (3, 156) = 31.41, p <.001, η_p^2 =.38. Post hoc pair wise comparison with Bonferroni correction revealed that participants were better at identifying what the speaker thinks than does (p<.001), feels (p<.001) or says (p<.001). The interaction between age group and individual scores on social exchanges was not significant, F (3, 156) = .68, p=.56, η_p^2 = .01. However, there was a significant interaction between individual components and condition, F (1,156) = 22.51, p <.001, η_p^2 =.30. The analysis revealed that there was no significant difference in the identification of individual components in the video condition. However, in the written form, participants performed significantly better on identification of what the speaker thinks than feels, t (25)=5.57, p<.001; does, t(25)=-9.82, p<.001, or says t(25)=-13.54, p<.001. Also, participants found it significantly easier to distinguish what the speaker does than says, t (25) =2.87, p=.01 and feels than says, t (25)=-3.58, p=.001. The three way interaction between the individual components, age group and condition was also not significant, F (1,156) = 1.21, p = .31, η_p^2 =.02.

Correlations

Correlations between accuracy on Part 2 and Part3 in the written and video conditions and the participant's chronological age, verbal abilities and speed of processing are illustrated in Table 6.6.

These correlations suggest that age has a strong effect on the written tasks as well as on the video tasks and this is stronger for Part 3 in the video form. Also it was found that participants who perform well on Part 2 in the written and video form have a better verbal ability and speed of processing than participants who perform less well. Moreover, in Part 3 performance on the video condition was mediated by speed of processing, but not in the written form

Table 6.6. Pearson correlations between accuracy on Part 2 and Part 3 in the written and video conditions and the participant's characteristics.

	Part 2	Part 3	WTAR	DSST
Written				
Part 2	-			
Part 3	.06	-		
WTAR	**.47***	.05	-	
DSS	**.54****	.20	.35	-
Age	**-.54****	-.36	-.33	**-.61****
Video				
Part 2	**-**			
Part 3	**.36***	-		
WTAR	**.37***	.30	-	
DSS	**.35***	**.61****	.09	-
Age	**-.47****	**-.53****	-.24	**-.63****

Note:WTAR = Wechsler Test of Adult Reading; DSST = Digit Symbol Substitution Test. Significant correlations those with * $p < .05$, ** $p < .01$.

Discussion

The aim of this experiment was to examine age effects on ToM tasks in written text and video based on the same social interactions. In line with previous studies (Slessor et al. 2007), it was expected that video presentation would produce larger age effects than would the same social information presented in written form. The results of this study do not support the prediction and shows that when social information presented in a video and written text is based on the same examples of social interactions, older adults perform poorly on both the video and written ToM tasks. The different patterns of findings from the current study and Slessor et al.

(2007) could be caused by several variables such as differences in stimuli, design or the uncontrolled degree of task difficulty. For instance, in the current experiment, participants were presented with video which includes sound whereas in the study of Slessor et al. (2007), the video was mute. As sound provides participants with extra cues it might make social information less ambiguous. Also, in the tasks used by Slessor et al. (2007), participants had to choose one word from an array of four to describe the feelings and thoughts of the character. In contrast, the TASIT provides participants with questions with straightforward 'Yes', 'No', 'Don't know' options, lessening the likelihood of difficulties with vocabulary.

Although the results of this experiment are in contrast to the study of Slessor et al. (2007) which showed age effects on video, but not written ToM performance, numerous studies have reported age related decline in processing ToM material in both written text and video (e.g. Maylor et al., 2002, Experiment 1; Sullivan and Ruffman, 2004). It was also previously reported that age affects performance on ToM tasks when information was presented to audio-visual channels stimultaneously (e.g. Ekman & O'Sullivan, 1991). Moreover, as argued in Chapter 2 (see also Hunter et al., 2010), older adults' poorer ability to detect incongruence from different sensory modalities could contribute to difficulties in decoding cues to deception, sarcasm or the masking of emotions. Indeed, they are numerous studies reporting that older adults display problems in identification of deceit. In one of the studies, Stanley and Blanchard-Fields (2008) compared the performance of young and older adults in the identification of lies. Both groups were presented with 20 interviews (either a crime interrogation or a social opinion interrogation) which could be presented via the auditory, visual or audio-visual mode. The study found that older adults were poorer at detecting deceit than younger adults in the condition where it mostly depended upon visual input. For instance, Stanley and Blanchard-Fields (2008) argue that ‘*older adults may be worse than younger adults at detecting deceit because they are less able to recognize facial expressions, which are key cues to deception*’ (p.24)., highlighting that older adults’ poorer deceit detection might be influenced by different conditions and types of task.

The importance of the type of task and its role in detecting age effects on ToM was highlighted by Saltzman et al. (2000) stressing that ToM tests are not very consistent and are not always measuring the same thing. For instance, in the aging literature, age effects were found on various ToM tests, e.g. short stories (Maylor et al., 2002), ToM in cartoons (Saltzman et al., 2000) and on reading the mind in the eyes (Phillips et al., 2002). In contrast, some studies report conflicting evidence where the age effects are not found on the ability to detect faux pas (e.g. MacPherson et al., 2002,) and in some cases age benefits were suggested, e.g. on short stories (Happé et al.,1998). One of the reasons accounting for different patterns of results might be related to the low ecological validity of ToM tasks.

It could be argued that traditional ToM tasks such as written stories or ‘posed’ images of emotions (McDonald et al., 2002, 2004) have little to do with social perception in real life. Therefore, to investigate whether performance of ToM tasks might be influenced by type of task with more ecologically valid stimuli, as opposed to written stories, both younger and older adults where assessed on ToM in video and written tasks based on the same social interactions (TASIT; Mcdonald et al., 2002, 2004). The results from both Part 2 and Part 3 suggests that younger and older adults were better in identifying social exchanges in video than in written text. It might be that the better performance of participants on the video rather than written text condition might reflect familiarity with the social exchanges and situations as they are similar to everyday interactions.

Indeed, .in Part 2 (minimal cues), both groups perform equally well in the identification of sincere exchanges, simple sarcasm and paradoxical sarcasm in video.In contrast,, in the written form where less paralinguistic social cues are available than in video form, participants were better in identifying paradoxical sarcasm than sincere exchanges or simple sarcasms. Similar patterns of results were found in Part 3 (enriched social cues) where participants had to identify lies and sarcasm. In the video condition, participants were able to identify lies and sarcasm equally well. However, in the written condition, both groups performed better in the detection of white lies. Also, in both Part 2 and Part 3 participants found it easier to identify the individual components of the stories (i.e. what people do, say, think & feel) in the video than in the written text. The results clearly demonstrate that participants performed better at identifying social exchanges in video form than written form as the information in a video provides people with more contextual and paralinguistic cues making social information less ambiguous.

The results of the correlations in the current experiment suggest that both the video and text conditions have a strong age effect on performance on ToM tasks. The correlational analysis revealed that in Part 2 when participants are presented with minimal cues about social situations, people that have higher verbal IQ perform better in both the written and video tasks. Other studies also suggest intellectual functioning might contribute to the performance on ToM tasks (e.g. Happé et al., 1998). In contrast in Part 3 where the cues about social situation are more explicit than in Part 2, the performance on the task is not associated with verbal abilities.

Moreover, in Part 2 with minimal cues, both the video and written task conditions were associated with speed of processing as demonstrated by performance on digit symbol substitution (DSS). This means that participants who perform well in the video and written condition in Part 2 had better verbal abilities and better speed of processing. Performance on the written task in Part 2 was also affected by age i.e. increased age was associated with poorer performance. In contrast, in Part 3 when older and younger adults received more cues regarding feelings and thoughts of a speaker in written condition, the correlation showed ToM was not mediated by verbal intelligence, speed of processing or increasing age. However, in the video form in Part 3, the performance on DSS was strongly associated with ToM performance, suggesting that people who scored better on DSS also scored high on the video condition. As working memory relies on speed of processing, the use of video in ToM where cues are incongruent such as those involved in detecting sarcasm and lies may put more demand on working memory load to comprehend information over written text, as suggested by Slessor et al. (2007).

In conclusion, the processing of paralinguistic and contextual social cues simultaneously in Part 3 might put more demand on speed of processing than information presented in the text which contain less social information. Moreover, in video condition, the dialogues are fast-paced whereas in the written text condition, participants can read stories in their own time, placing fewer demands on working memory and speed of processing. Nevertheless, in order to draw a definitive conclusion about the association between performance on ToM and general cognitive functioning more careful measures and a larger group sample is required.

Conclusion

Overall, results of the current study indicate that older adults perform less well than do younger adults on identification of both sarcasm and lies in either video or written form. Both groups performed better on video than on written forms, suggesting that video provided more social relevant cues than did the written text condition. The results also suggest that older adults are impaired on ToM and this might be related to general cognitive decline.

Chapter 7: General Discussion

Thesis Aim

The aim of this thesis was to investigate the relationship between multisensory integration and social cognition in adult aging with a particular interest in whether understanding the mental and emotional states of others could be enhanced through multisensory integration. A series of experiments were designed to compare the performance of younger and older adults on tasks related to multisensory integration and social cognition.

Chapter 2: The effects of healthy adults aging on unimodal and cross-modal emotion perception

Chapter 2 was designed to investigate whether older adults benefit from multisensory integration when identifying emotional expressions. In line with previous findings (Ruffman et al., 2008), the results indicate that older adults had difficulty in identifying negative emotions unimodally from faces and voices (Experiments 1 & 2). One key theory postulates that older adults have difficulty in recognizing negative emotions because through a lifetime of experience in monitoring and regulating emotions, they have developed a bias to attend away from negative information and instead focus on the positive (see, Carstensen et al., 1999; Mather & Carstensen, 2003). It has been suggested that attending to positive events in social interactions has numerous benefits, such as better management of personal and social conflict (Blanchard-Fields, Mienaltowski, & Seay, 2007), whereas others postulate that attending only to positive information and ignoring negative can have adverse effects (Löckenhoff & Carstensen, 2004). For example, '*when decisions require that people consider negative as well as positive options, a preference for positive information could lead to poor-quality decisions*' (Löckenhoff & Carstensen, 2004, p.120).

Although older adults performed poorer in the identification of negative emotions in one modality, it was found that age differences in emotion perception were removed when congruent multimodal information was available. Evidence supporting the notion that older adults might benefit from multisensory channels when interpreting emotions was found in tasks where older adults were as good as younger adults at detecting congruence in cross-modal emotional cues (Experiment 3) and explicitly identifying emotions from cross-modal cues (Experiment 4). In Chapter 2, it was also hypothesized that older adults might have difficulty in perceiving incongruency across different sensory channels. Given the well-documented difficulties with controlled inhibition of irrelevant information in older adults (Hasher & Zacks, 1988), older adults were predicted to perform more poorly than younger adults on the cross-modal incongruent trials. The results of Experiment 3 suggest that adults had particular difficulty in identifying when two sources of emotional information were incongruent, which may be linked to more general difficulties in processing conflicting information in old age.

Chapter 3: The effects of healthy adults aging on cross-modal Stroop task

The key finding from Chapter 2 suggested that older adults benefit from cross-modal congruent information but have difficulty in perceiving non-matching information across different emotional channels. The issue whether age related differences in dealing with congruent and incongruent cross modal integration are specific to social interaction or cognitive control in general was addressed in Chapter 3. In this experiment, the same cross-modal Stroop like paradigm as in Experiment 2 was used. However, the faces and voices were replaced with emotionally neutral stimuli, i.e. colour patches and verbalisations of colour words replicating the cross-modal colour word Stroop task. The results from Chapter 3 suggest that older adults benefit more than younger adults from the cross-modal congruent presentation of non-emotional information than information presented only to one modality, as was found with emotional stimuli in Chapter 2. However, younger but not older adults performed faster in the control condition compared to the incongruent condition showing Stroop interference. Finally, both younger and older adults showed a similar sized cross modal congruency effect, i.e. responding faster to congruent than to incongruent information.

In line with evidence showing that the way people manage their emotions is often related to general cognitive functioning, it was also investigated whether recognizing emotions might be related to general cognitive functioning. For instance, Mather and Knight (2005) postulated that cognitive control plays a fundamental role in older adults' emotion-regulation and emotion recognition abilities. The results of the correlational analysis indeed suggest that certain aspects of social cognition, such as recognizing emotions might be related to general cognitive functioning, i.e. selective attention or response inhibition in particular.

Chapter 4: Age, eye movements and emotional matching

The findings from Chapter 2 illustrates that older adults perform as well as younger in matching faces to voices when the two sources of information are congruent. In contrast, when older adults had to integrate incongruent audio-visual information, they performed less well than younger adults. It has been proposed that older adults' poorer ability to detect incongruence might be due to well documented difficulties in inhibiting incongruent source of information (e.g. Chapter 2; Hasher & Zacks, 1988). However, there might be other underlying reasons contributing to older adults' difficulties in detecting cross-modal emotional incongruence such as age related changes in gaze behaviour when looking at the emotional faces. Indeed, the results from Chapter 4 show that older and younger adults differ in their strategies when looking at emotional faces presented with congruent and incongruent voices highlighting that our audio-visual system is interactive and might be influenced by life-span developmental changes. The results indicate that older adults who gaze longer at the eye area perform better at detecting cross-modal incongruence than older adults with shorter fixations on the eye region. In contrast, it seems that younger adults who spend less time looking at both the eye and mouth areas perform more accurately when detecting cross-modal incongruence. When emotions portrayed on the face are paired congruently with a voice, older adults who look for a shorter time at both the eye and mouth regions are better at detecting cross-modal congruence than those older adults who look for longer. In contrast, younger adults who look longer at the whole face including the eyes, mouth and also the periphery of the face perform best at congruence detection.

It was also found that gazing only at the eye region was not related to better accuracy performance in either group in the condition where faces are paired congruently with voices. Likewise, time spent fixating on the mouth only area in the congruent and incongruent conditions was not related to younger and older adults' ability to accurately match face-voice pairings.

Chapter 5: Integrating social information following stroke

This chapter addressed important issues related to emotional functioning in stroke, which is still a neglected subject when compared with neurological studies looking at sensory, motor or cognitive functioning post stroke (Rosen & Levenson, 2009). Moreover, the literature looking at multisensory integration in neuropsychological populations is also very limited, with only a few studies looking at multisensory integration in psychiatric patients, in particular schizophrenia (e.g. de Gelder, Vroomen, Annen, Masthof, & Hodiamont, 2003; de Jong, Hodiamont, Van den Stock, & de Gelder, 2009; Williams, Light, Braff, & Ramachandran, 2010). The general results from people with schizophrenia suggest that they have reduced ability to integrate emotional information from faces and voices, where patients suffering with schizophrenia are less influenced than controls by emotional expressions presented on faces while judging emotion presented in the voice (de Jong et al., 2009). Nevertheless, up to now, none of the studies addressed how neurological patients integrate multisensory emotional information.

Therefore, Chapter 5 investigated whether the changes in behaviour and social interaction often reported in patients post-stroke relate to problems in integrating cross-modal social information and the inability to recognise emotions from faces and voices. This study found that stroke patients who show changes in social behaviour are more likely to have difficulty integrating cross-modal social information but perform as well as healthy control on tasks where participants are required to recognize emotion presented in one modality. The results from this chapter also indicate that tasks assessing the integration of cross-modal emotional information may be more sensitive to stroke and social behaviour problems, than traditional unimodal tasks. Moreover, the resulting data show that when the neural network is damaged by stroke, individuals who display behavioural changes post-stroke no longer benefit from congruent cross-modal stimuli. However, the core question that should be addressed in future studies is why older adults benefit from congruent multisensory integration of emotions but stroke patients do not. Are there specific neural substrates for crossmodal congruent and incongruent conditions with relation to emotions? To this date, these questions remain unanswered.

Chapter 6: Effects of age and type of task on Theory of Mind (ToM) performance

Finally, Chapter 6 highlights the need for ecologically valid tasks and looks at age related differences using a more real-life paradigm. In everyday social situations, the presentation of emotions is not contextually and perceptually restricted, and it seems very unlikely that people will ever interact with static emotional expressions or acted vocalisations of emotional signals. Moreover, to successfully understand social situations, people have to integrate emotional signals through multiple sources. However, in order to support the claim that people would perform better on tasks depicting real life situations, using video, it was necessary to compare performance on video tasks with other widely used ToM tasks such as written text. Hence, in this chapter the age effects on theory of mind (ToM) performance on two different types of task were assessed. The study compared the performance of younger and older adults on stories and video tasks based on identical social interactions. In line with previous experiments e.g. Slessor et al. (2007), it was expected that social information presented through video will be more sensitive to aging than information presented through text, as processing information in a video might require greater demands on executive processes and working memory where multiple aspects of social information is processed simultaneously.

Overall, the results indicate that older adults perform less well than younger adults in the identification of both sarcasm and lies in both video and written text. One of the underlying reasons for this finding might be that older adults are more reluctant to accept the negative event, such as those involved in detecting sarcasm or lying (e.g. Stanley & Blanchard-Fields, 2008; Mather & Carstensen, 2003). This is in line with the Social Selectivity Theory (SST; Carstensen et al., 2003) postulating that identifying negative emotions and events e.g. deceit might be particularly sensitive to aging as older adults pay more attention to positive information than negative and optimize positive emotions at the cost of negative emotions.

However, both groups performed better on the video rather than the written forms, suggesting that video provided more relevant cues than the written text. The further results suggest that older adults are impaired on ToM and this might be related to general cognitive decline.

Limitations and future directions

Dynamic stimuli and facial mimicry

An important methodological issue that should be addressed in future studies is the use of static facial expressions which do not reflect the presentation of real emotions in everyday situations. Several studies report that the use of dynamic faces as opposed to static faces in photographs provides us with more information about emotions (e.g. Ambadar, Schooler, & Cohn, 2005). For instance, facial movements in dynamic faces when compared with photographs were shown to improve the ability to recognise emotional expressions (Biele & Grabowska, 2006) '*as the motion in dynamic faces provides independent information about identity and emotional expression that is not available in posed, static faces*' (Buchan et al., 2007, p.1). Indeed, it has been reported that facial mimicry can contribute to better recognition of emotions (e.g. Atkinson & Adolphs, 2005; Oberman, Winkielman, & Ramachandran, 2007) and when mimicry is disrupted it contributes to poorer emotion detection (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001). Therefore, presenting participants with dynamic faces might improve their ability to identify emotional expressions. For instance, a recent study by Krendl and Ambady (2010) indicates that older adults show a decline in the recognition of anger from static faces, but not from dynamic images of faces. Moreover, it has been previously suggested that the major regions of the brain involved in processing emotional expressions portrayed on the faces e.g. amygdala, the posterior superior temporal sulcus (pSTS) and insula are more activated by dynamic than static faces displaying emotions (Collignon et al., 2008; Haxby, Hoffman, & Gobbini, 2002).

To better understand age effects in cross-modal matching of congruent and incongruent social information, it might be necessary to readdress age effects in processing multisensory information in dynamic faces. Using dynamic faces reflects a more naturalistic task, as in social situations people are exposed to dynamic facial movements. Nevertheless, up to now most aging studies have used static faces, as dynamic emotional stimuli with reliable standardisation have not yet been developed. The development of standardized emotional dynamic stimuli would require information from audio-visual sources such as: emotional, linguistic and pragmatic cues which are congruent in every aspect. It might be that the presentation of congruent information to multimodal channels might remove age differences.

Hence, considering that older adults benefit from congruent cross-modal cues in emotion perception when using static facial stimuli, it would be interesting to look if older adults would benefit even more form congruency when using dynamic faces.

Gender differences in emotion perception

In addition to other variables which might have influenced our results such as lack of dynamic stimuli, it is also important to consider gender differences. It has been suggested that the processing of emotional prosody might be influenced by gender. For instance, women tend to process sentences which are congruent in terms of meaning with voice prosody faster than men (e.g. Besson, Magne, & Schön, 2002). Gender differences are also found in processing erotic voice prosody where '*men and women attribute higher arousal ratings to erotic prosody expressed by speakers of the opposite rather than same sex*' (Ethofer et al., 2007, p.336).

Several studies have also suggested that women are better at identifying emotions portrayed on the face than men (e.g. Hall, 1978; Biele & Grabowska, 2006). However, most of the research on emotion perception from faces used pictures of static emotional expressions, and only a few studies have investigated gender related differences in processing multisensory emotion expression. The most recent study by Collignon et al. (2010) found that women tend to integrate multisensory emotional stimuli more efficiently than males suggesting that differences in processing multisensory emotional information might also be influenced by gender differences. In our experiments it was not possible to fully address gender differences due to insufficient power. However, there were no age differences in gender distribution.

Neural networks, consciousness and emotions

The resulting data form Chapter 2 suggest that both younger and older adults perform better in judging accuracy when face-voice pairings in emotion matching tasks are congruent than incongruent. It has been documented that when multisensory integration is congruent, it enhances our neural network resulting in better accuracy (Stein & Meredith, 1986). However, when incongruent multisensory information is integrated into the multisensory neural network it decreases its activity causing decrements in performance, i.e. poorer ability to decode emotions. According to componential appraisal models (Grandjean, Sander, & Schrerer, 2008), emotions are described as a '*dynamic episode in the life of an organism that involves a process of continuous change in all of its subsystems (e.g. cognition, motivation, physiological reactions, motor expressions, and feeling – the component of emotion)* *to adapt flexibly to events*' (Grandjean et al., 2008, p.485). Grandjean et al. (2008) argue that building up subjective feelings is equated with conscious representation and involves a '*complex dynamic phenomenon implying neuronal synchronizations at different levels*' (p.493). It might be that when emotions presented in the face and the voice are congruent, it results in better neural synchronisation helping to evoke conscious feeling and in turn better recognition of emotions. However, when emotion on the face is incongruent with emotion in the voice, it may slow multisensory integration and reduce the likelihood of conscious emotional reactions to emerge in response to stimuli causing poorer performance in accuracy (Grandjean et al., 2008). It would be interesting to investigate when the synchronization of different inputs reaches a level that permits consciousness. This would involve examining whether participants' performance on congruent and incongruent emotion recognition tasks is related to oscillatory activity underlying the emergence of consciousness as measured by electroencephalography (EEG) gamma and beta bands (Dan Glauser & Scherer, 2008).

Personality and emotional intelligence

Research on personality shows that increased age might be associated with changes in personality dimensions (McCrea & Costa, 2003; Mill, Allik, Realo, & Valk, 2009). It has been suggested that older people tend to score higher on agreeableness and conscientiousness, and lower on extraversion and openness (McCrea & Costa, 2003; Mill et al., 2009). It has been also previously postulated that the ability to recognize emotions might depend on personality traits and that people with high scores on openness tend to recognize emotions particularly well

(Matsumoto et al., 2000; Realo et al., 2003). In other studies the relationship between agreeableness and performance on ToM tasks has also been reported (e.g. Ferguson & Austin, 2010; Nettle & Liddle, 2008). Moreover, how people perform on ToM tasks such as recognizing emotions or inferring mental states of others could be influenced by their emotion-related skills such as emotional intelligence (EI). To measure individuals emotional ability it is important to assess their trait emotional intelligence that '*regards EI as being located within the personality domain'* (Austin, 2010, p. 564), and emotional intelligence ability which*' relates to reasoning and problems solving in the emotional domain'* (Austin, 2010, p.564). Both trait and ability emotional intelligence are believed to be related to general social competence (Ferguson & Austin, 2010). It would be interesting to examine if there are age-related differences on trait and ability emotional intelligence and personality measures and how this measures relate to performance on various ToM tasks, e.g. socio-cognitive (e.g. Faux Pas stories presented in written and video form) or perceptual tasks (e.g. recognizing emotions from faces or other non-verbal cues).

Multisensory integration and cognitive abilities

Another important question to be addressed in future research is whether information presented to multiple channels might help older adults to compensate for their general cognitive decline. This might be particularly relevant for older adults when comprehending health messages as successful comprehension of health information might help older adults to remain more healthy and independent. Recent data suggest that only 3% of older adults over 65 years old have sufficient health literacy skills (Kutner, Greenberg, Jin, & Paulsen, 2006) and that low health literacy is associated with higher hospital admission rates, an inability to manage chronic diseases, and increased mortality (e.g., Baker, et al., 2007; Sudore et al., 2006). As successful understanding of health messages involves cognitive processes, such as working memory (e.g., Wilson & Wolf, 2009), which are likely to be particularly important in comprehending written health information for older people (Benson & Forman, 2002; Gazmararian et al., 1999; Williams et al., 1995), it would be interesting to examine whether older adults benefit from health information presented to multiple sensory channels (through video).

Considering the evidence that older adults benefit more than younger adults from the simultaneous presentation of congruent multisensory information over information presented in one modality (see Chapter 2; Hunter et al., 2010; Laurienti et al., 2006), the presentation of health information via multiple sensory modalities might be especially important. Therefore, future studies should investigate the effects of multisensory presentation (videos) versus unisensory presentation (text) on the comprehension of health information in older adults. It might be that the use of video over text may be especially beneficial for older adults who are already challenged by perceptual and reading difficulties. Moreover, presenting health information cross-modally might aid both the understanding and retention of important health messages.

Thesis summary

The aim of this thesis was to investigate the relationship between multisensory integration and social cognition in adult aging. The overall results suggest that younger and older adults process multisensory social information differently. When participants have to match emotional faces to voices or explicitly identify emotions through a cross-modal task, older adults perform as well as younger adults when the auditory and visual emotional information are congruent, but have difficulty in identifying incongruent information. These age differences in the processing of relevant and irrelevant visual and auditory social cues might be related to changes in gaze behaviour and the type of social task used. Moreover, tasks assessing the multisensory integration of emotions are more sensitive to stroke and social behaviour problems than traditional social cognition tests. The results from this thesis provide us with clear evidence that our senses are harmoniously synthesized and influence the way we perceive, understand and manage the social world around us.

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Appendices

Appendix 1: Screening Tests

Experiments 1, 2, 3 and 5

Table A.1. Means and standard deviations of screening tests for older adults.

	Older Adults (n = 25)	
	M	*SD*
Mini Mental State Examination	29.60	.63
Benton Facial Recognition	45.53	1.88
FAB: Nonemotional Prosody Discrimination	15.93	.26
FAB: Emotional Prosody Discrimination	19.80	.41

Note: FAB = Florida Affective Battery

Experiment 4

Table A.2. Means and standard deviations of screening tests for older adults.

	Older Adults (n = 20)	
	M	*SD*
Mini Mental State Examination	28.85	1.60
Benton Facial Recognition	50.25	3.14
FAB: Nonemotional Prosody Discrimination	15.45	.82
FAB: Emotional Prosody Discrimination	19.75	.55

Note: FAB = Florida Affective Battery

Experiment 6

Table A.3. Means and standard deviations of screening tests for older adults.

	Older Adults (n = 12)	
	M	SD
Mini Mental State Examination	29.00	1.28
Benton Facial Recognition	45.83	2.95
FAB: Nonemotional Prosody Discrimination	15.83	.39
FAB: Emotional Prosody Discrimination	19.75	.62

Note: FAB = Florida Affective Battery

Experiment 7

Table A.4. Means and standard deviations of screening tests for stroke patients and healthy control.

	Control (n = 7)		Stroke Patients (n = 8)	
	M	SD	M	SD
Mini Mental State Examination	29.43	1.28	28.50	.92
Benton Facial Recognition	44.71	2.95	46.14	4.84
FAB: Nonemotional Prosody Discrimination	15.86	.39	15.86	.38
FAB: Emotional Prosody Discrimination	19.86	.38	19.57	.79

Note: FAB = Florida Affective Battery

Experiment 8

Table A.8. Means and standard deviations of screening tests for older adults.

	Older Adults (n = 12)	
	M	SD
Mini Mental State Examination	29.47	.87
Benton Facial Recognition	45.67	1.58
FAB: Nonemotional Prosody Discrimination	15.89	.33
FAB: Emotional Prosody Discrimination	19.67	.50

Note: FAB = Florida Affective Battery

Appendix 2: Instructions for Participants: Facial Expression of Emotions (FEEST)

This test assesses ability to recognize facial expressions. You will see a series of pictures of faces. For each face, you must decide whether its expression is most like happiness, sadness, surprise, fear, disgust or anger.

You can make your response by pressing one of the buttons on the screen.

The faces are shown for a few seconds each, but you can take as long as you wish to decide on the emotion.

Appendix 3: Instructions for Participants: Prosodic Emotion Identification

This test assesses ability to recognize vocal expressions. You will hear via headphones vocal expression of emotions, for instance somebody crying, laughing, being angry, etc.

For each voice, you must decide whether its expression is most like happiness, sadness (crying), surprise, fear, disgust or anger, by pressing the appropriate key:

H – Happy

C – Crying

D- Disgust

S – Surprise

F- Fear

A - Anger

You can make your response by pressing one of the buttons on the keyboard or ask somebody to do it for you.

The voices will be of short duration, but you can take as long as you wish to decide on the emotion.

Appendix 4: Instructions for Participants: Emotion Matching Task

You will be presented with sound through headphones and a picture of a facial expression at the same time presented on the computer screen.

The pictures will represent different facial emotions, such as happiness, anger, sadness, surprise, fear or disgust. The sounds will also express these emotions, for instance: a person laughing, crying etc.

You have to attend to the emotional expression of a face and judge if this expression matches the vocal emotion presented by headphones.

If the face expression presented on the screen is the same as the emotion presented by headphones, e.g.: Happy-"Laughter" you have to press marked key "S"(Same).

If the facial expression presented on the screen is different from the emotional expression presented by headphones e.g. Happy-"Crying" you have to press marked key "D"(Different).

On some occasions the picture of facial expression will appear without sound therefore "V" (Visual only) should be pressed.

Please respond as quickly and accurately as possible.

Appendix 5: Instructions for Participants: Explicit Emotion Identification Task

You will hear a sound through headphones and at the same time see a picture of a facial expression on the computer screen.

The pictures will represent different facial emotions such as anger, sadness, fear or disgust. The sounds will also express these emotions, for instance: a person laughing, crying etc.

On some occasions faces will appear without voices and voices without faces.

For each trial, you must decide whether the expressions are most like sadness, fear, disgust or anger by pressing the appropriate key:

S - Sadness

D - Disgust

F - Fear

A – Anger

Please respond as quickly and accurately as possible.

Appendix 6: Instructions for Participants: Cross-modal Stroop Task

You will be presented with the auditory stimuli through headphones whereas the visual stimuli will be presented on the computer screen. In this task you have to judge if the colour patch on the screen matches the word presented by headphones. If the colour patch on the screen is the same as the word presented via headphones, for instance: "RED"-RED you have to press the key marked "S"(Same).

If the colour patch presented on the screen is different from the word presented in auditory modality, e.g. "RED"-BLUE you have to press the key marked "D"(Different).

On some occasions the colour patch will appear without the auditory stimuli therefore you are required to press "V" (Visual only).

Please respond as quickly and accurately as possible.

Appendix 7: Instructions for Participants: Eye Movements and Emotional Matching Task.

You will be presented with sound through headphones and a picture of a facial expression at the same time presented on the computer screen.

The pictures will represent different facial emotions anger, sadness, surprise, fear or disgust. The sounds will also express emotions, for instance: a person laughing, crying etc.

You have to attend to the emotional expression of a face and judge if this expression matches the vocal emotion presented by headphones.

If the face expression presented on the screen is the same as the emotion presented by headphones, e.g.: Happy-"Laughter" you have to press marked key "S"(Same).

If the facial expression presented on the screen is different from the emotional expression presented by headphones e.g. Happy-"Crying" you have to press marked key "D"(Different).

Please respond as quickly and accurately as possible.

Appendix 8: Example of the invitation letter to participants

Psychology
SCHOOL *of* PHILOSOPHY, PSYCHOLOGY *and* LANGUAGE SCIENCES

The University of Edinburgh
7 George Square
Edinburgh EH8 9JZ

Telephone 0131 650 3440
or direct dial 0131 650
Fax 0131 650 3461
Email Psychology@ed.ac.uk

PRIVATE & CONFIDENTIAL
NAME
ADDRESS 1
ADDRESS 2
ADDRESS 3
ADDRESS 4

Dear

I am writing to tell you about some research that I am conducting in collaboration with Dr Sarah MacPherson at University of Edinburgh and Prof Louise Phillips at University of Aberdeen. The aim of this study is understand how we deal with visual and auditory emotional information in social situations. If you choose to enter the study, you will be asked to complete some tests which take no longer than 1 hour 30 minutes to complete.

Please find enclosed the participant information sheet, which provides more information. If you would be interested in taking part, or would simply like to discuss in more detail what would be involved, please feel free to contact myself or Dr Sarah MacPherson.

Please do not feel that you are under any obligation to take this any further should you not wish to do so.

Yours sincerely,

Mrs Edyta Monika Hunter
e.m.hunter@ed.ac.uk

Appendix 9: Example of information sheet for participants

Psychology
SCHOOL *of* PHILOSOPHY, PSYCHOLOGY *and* LANGUAGE SCIENCES

The University of Edinburgh
7 George Square
Edinburgh EH8 9JZ

Telephone 0131 650 3440
or direct dial 0131 650
Fax 0131 650 3461
Email Psychology@ed.ac.uk

Information Sheet for Participants

Study title: Age effects on explicit cross-modal emotion identification.

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The purpose of this study is to investigate whether age affects the ability to integrate emotional cues from faces and voices in social situations.

Why have I been chosen?

You have been chosen as you are a volunteer on the participant panel of the Department of Psychology, University of Edinburgh. We will be seeing a total of sixty healthy volunteers: 30 aged 20-40 years and 30 aged 60-80 years.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

All volunteers will be asked to perform a series of tests, some of which take place on a laptop computer and some of which are paper and pencil. The time taken to complete the tests will take no longer than 1 hour 20 minutes. If you need a break at any time you are free to do so.

During the interview, there are tests in which we would like to record you. This is because the tests require you to tell us the answers out loud. By recording your answers, we do not need to write everything down immediately as you say it. We will ensure, however, that these recordings will be stored on a password protected computer and they will be destroyed once your answers have been written down and scored.

What do I have to do?

The tasks are in the form of "paper and pencil" tests and computer tests. The instructions for each test would be explained to you beforehand.

What are the possible disadvantages and risks of taking part?

There are no risks of the study. However, your participation in the study is entirely voluntary and you are free to decline to enter or to withdraw from the study any time without having to give a reason.

What will happen to the results of the research study?

The final results will be written up as part of a PhD thesis and be written up for publication in peer reviewed journals. Talks and presentations may be made at meetings and conferences. In all cases, your name and personal details will not be identified.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you will have your name removed so that you cannot be recognised from it. You will be allocated an anonymous ID code during testing which will be used in place of your name on any future publications.

Who has reviewed the study?

This study has been granted ethics approval by School of Psychology Ethics Committee.

Contact for further information

If you wish to ask anything further, please contact Mrs Edyta Monika Hunter or Dr Sarah MacPherson at the following address:

Department of Psychology, PPLS

7 George Square

Edinburgh, EH8 9JZ

Or via the following telephone number or email address:

Mrs Hunter on 0131 650 3455 (e.m.hunter@ed.ac.uk)

Dr MacPherson on 0131 650 9862 (sarah.macpherson@ed.ac.uk)

Thank you for reading this information sheet. You will be given a copy to keep. If you have understood the contents of this sheet and wish to take part, please complete the consent sheet on the next page. If you have any questions please feel free to ask them now.

Appendix 10: Example of consent form

Study Number: *****

Control Identification Number for this trial:

CONSENT FORM - Confidential

Title of project: **Age effects on explicit cross-modal emotion identification.**

Please initial box

1. I confirm that I have read and understand the information sheet dated 26/07/09 for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐
3. I understand that my voice will be audio taped for the purpose of the study. ☐
4. I am aware that any data collected will be confidential. ☐
5. I agree to take part in the above study. ☐

____

Name of Participant	Date	Signature

____

Name of Person taking consent	Date	Signature

Appendix 11: Exclusion criteria

PLEASE LET THE EXPERIMENTER KNOW IF ANY OF THE FOLLOWING APPLY. YOU DO NOT HAVE TO STATE WHICH ONE.

- **Colour-blindness**
- **Uncorrected hearing loss**
- **Uncorrected visual impairment**
- **Current treatment for alcohol or drug dependence**
- **Seeing a doctor or other professional for memory problems or problems with thinking**
- **A condition that would prevent arm movement and/or the use of both hands**
- **Any period of unconsciousness for 5 minutes or more**
- **Head injury resulting in hospitalisation for more than 24 hours**
- **Currently taking antidepressant, anti-anxiety, or anti-psychotic medication**
- **Medical or psychiatric condition that could potentially affect cognitive functioning, such as:**

    Stroke
    ECT (electric shock treatment)
    Epilepsy
    Brain surgery
    Encephalitis
    Meningitis
    Multiple sclerosis
    Parkinson's disease
    Huntington's chorea
    Alzheimer's dementia
    Schizophrenia
    Bipolar disorder

Appendix 12: FrSBe Self Rating Form

FRONTAL SYSTEM BEHAVIOUR SCALE

(FrSBe)

Self-Rating Form

Janet Grace, PhD, and Paul F. Malloy, PhD

Name ______________________ Gender__________ Age _____ Today's date ____/____/____

Education level (check one): ☐ 12 years or less ☐ More than 12 years

Date of onset of illness/injury ____/____/____

1	2	3	4	5
Almost never	Seldom	Sometimes	Frequently	Almost always

	Before illness or injury	**At the present time**
1. I speak only when spoken to.	1 2 3 4 5	1 2 3 4 5
2. I am easily angered or irritated; I have emotional outbursts without good reason.	1 2 3 4 5	1 2 3 4 5
3. Repeat certain actions or get stuck on certain ideas.	1 2 3 4 5	1 2 3 4 5
4. I do things impulsively.	1 2 3 4 5	1 2 3 4 5
5. Mix up a sequence, get confused when doing several things in a row.	1 2 3 4 5	1 2 3 4 5
6. Laugh or cry too easily.	1 2 3 4 5	1 2 3 4 5
7. Make the same mistakes over and over, do not learn from past experience.	1 2 3 4 5	1 2 3 4 5
8. Have difficulty starting an activity, lack initiative, motivation.	1 2 3 4 5	1 2 3 4 5
9. Make inappropriate sexual comments and advances, am too flirtatious.	1 2 3 4 5	1 2 3 4 5
10. Do or say embarrassing things.	1 2 3 4 5	1 2 3 4 5
11. Neglect my personal hygiene.	1 2 3 4 5	1 2 3 4 5
12. Can't sit still, am hyperactive.	1 2 3 4 5	1 2 3 4 5
13. Am unaware of my problems or when I make mistakes.	1 2 3 4 5	1 2 3 4 5
14. Sit around doing nothing.	1 2 3 4 5	1 2 3 4 5
15. Am disorganized.	1 2 3 4 5	1 2 3 4 5
16. Lose control of my urine or bowels and it doesn't seem to bother me.	1 2 3 4 5	1 2 3 4 5
17. Cannot do two things at once (for example, talk and prepare a meal).	1 2 3 4 5	1 2 3 4 5
18. Talk out of turn, interrupt others in conversations.	1 2 3 4 5	1 2 3 4 5
19. Show poor judgment, poor problem solver.	1 2 3 4 5	1 2 3 4 5
20. Make up fantastic stories when unable to remember something.	1 2 3 4 5	1 2 3 4 5
21. Have lost interest in things that used to be fun or important to me.	1 2 3 4 5	1 2 3 4 5
22. Say one thing, then do another thing.	1 2 3 4 5	1 2 3 4 5
23. Start things but fail to finish them, "peter out."	1 2 3 4 5	1 2 3 4 5
24. Show little emotion, am unconcerned and unresponsive.	1 2 3 4 5	1 2 3 4 5

1 Almost never	2 Seldom	3 Sometimes	4 Frequently	5 Almost always	Before illness or injury	At the present time
25. Forget to do things but then remember when prompted or when it is too late.					1 2 3 4 5	1 2 3 4 5
26. Am inflexible, unable to change routines.					1 2 3 4 5	1 2 3 4 5
27. Get in trouble with the law or authorities.					1 2 3 4 5	1 2 3 4 5
28. Do risky things just for the heck of it.					1 2 3 4 5	1 2 3 4 5
29. Am slow moving, lack energy, inactive.					1 2 3 4 5	1 2 3 4 5
30. Am overly silly, have a childish sense of humor.					1 2 3 4 5	1 2 3 4 5
31. Find that food has no taste or smell.					1 2 3 4 5	1 2 3 4 5
32. Swear.					1 2 3 4 5	1 2 3 4 5
Read each of the following items carefully before responding.						
33. Apologize for misbehavior (for example, apologize for swearing).					1 2 3 4 5	1 2 3 4 5
34. Pay attention, concentrate even when there are distractions.					1 2 3 4 5	1 2 3 4 5
35. Think things through before acting (for example, consider finances before spending money).					1 2 3 4 5	1 2 3 4 5
36. Use strategies to remember important things (for example, write notes to myself).					1 2 3 4 5	1 2 3 4 5
37. Am able to plan ahead.					1 2 3 4 5	1 2 3 4 5
38. Am interested in sex.					1 2 3 4 5	1 2 3 4 5
39. Care about my appearance (for example, daily grooming).					1 2 3 4 5	1 2 3 4 5
40. Benefit from feedback, accept constructive criticism from others.					1 2 3 4 5	1 2 3 4 5
41. Get involved with activities spontaneously (such as hobbies).					1 2 3 4 5	1 2 3 4 5
42. Do things without being requested to do so.					1 2 3 4 5	1 2 3 4 5
43. Am sensitive to the needs of other people.					1 2 3 4 5	1 2 3 4 5
44. Get along well with others.					1 2 3 4 5	1 2 3 4 5
45. Act appropriately for my age.					1 2 3 4 5	1 2 3 4 5
46. Can start conversations easily.					1 2 3 4 5	1 2 3 4 5

Appendix 13: Key Search Task (BADS)

During administration of this test, one of the patients (CW) could not grasp the concept of 'not knowing' where he lost his own keys, due to his problem with abstract reasoning often related to frontal lobe damage (Wilson et al., 1996). The patient (CW) insisted during the application of the test that he would know where he had lost his keys as he would exactly know where he was walking. Therefore, the examiner decided to deliver the second set of instructions from a third person perspective.

In the Key Search test, the patient was presented with an A4-sized piece of paper with a 100mm square in the middle and a black dot 50 mm below it representing the field. Patients had to imagine that they lost their keys somewhere in the field and they were asked to draw a line representing how they would walk within the field to ensure that they will find the keys. The task is believed to be analogous to real-life activity and examines patients' ability to plan and monitor their performance.

In the original test and the first key search task, the patient is delivered with the following instructions:

'*I want you to imagine that this square is a large field. Somewhere in this field you have lost your keys. You don't know exactly where you have lost them because you have been all over the field, all you know is that they are somewhere in the field.*

Starting from this dot I want you to draw a line with the pen to show me where you would walk to search the field to make absolutely certain that you would find your keys no matter where they were.'

In the second attempt on the key search task, patients were delivered with the following instruction:

'*I want you to imagine that this square is a large field. Somewhere in this field John has lost his keys. You don't know exactly where he has lost them because he has been all over the field, all you know is that they are somewhere in the field.*

Starting from this dot I want you to draw a line with the pen to show me where you would walk to search the field to make absolutely certain that you would find John's keys no matter where they were'.

The marking system shows that entering and leaving the field at the corners gains more points than at the base (maximum of 3 marks), pattern of vertical and horizontal lines are awarded more marks than concentric ones (1 mark for parallel and 1 mark for vertical/horizontal lines) and single planned patterns gain more marks than duplicated or multiple ones (maximum of 5 marks). In addition, one mark is awarded for each of the following: drawing line continuously, attempting to cover all the ground and search strategy, giving a maximum total of 16 marks for this task.

Results

During assessment it was found that patients had difficulty with performing the key search task. After changing the instructions from the first person to third person, the score on the key search task by patient WC improved from 4 to 15 points. The opposite pattern was found for patient FH who performed better on the task from the first person perspective than the third person perspective.

Table 1. Scoring of WC and FH on the key search task from the first and third perspective.

	WC		FH	
	First Person	Third Person	First Person	Third Person
1 Entering the field	2	2	2	2
2 Finishing the search	1	3	1	1
3 Continuous line	1	1	1	1
4 Parallel lines	0	1	0	0
5 Vertical/horizontal	0	1	1	1
6 Patterns	0	5	3	3
7 Covering all ground	0	1	1	0
8 Finding the keys	0	1	1	0
Total	4	15	10	8

Figure 1. Performance on the key search task by CW from the perspective of the first person.

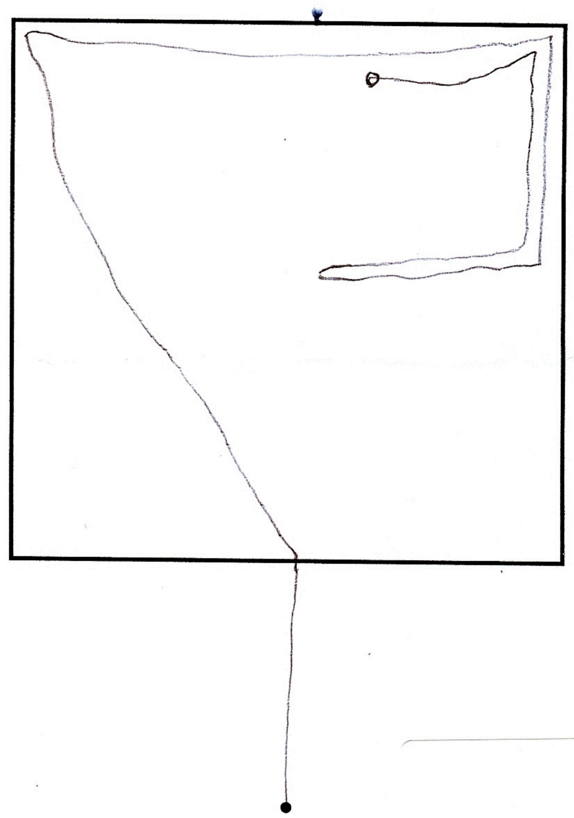


Figure 2. Performance on key search task by CW from the perspective of the third person.

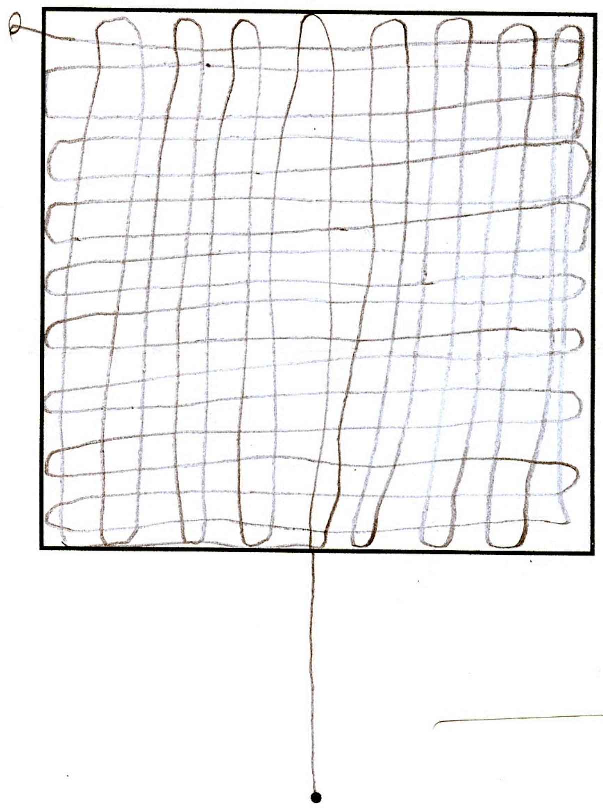


Figure 3. Performance on key search task by FH from the perspective of the first person.

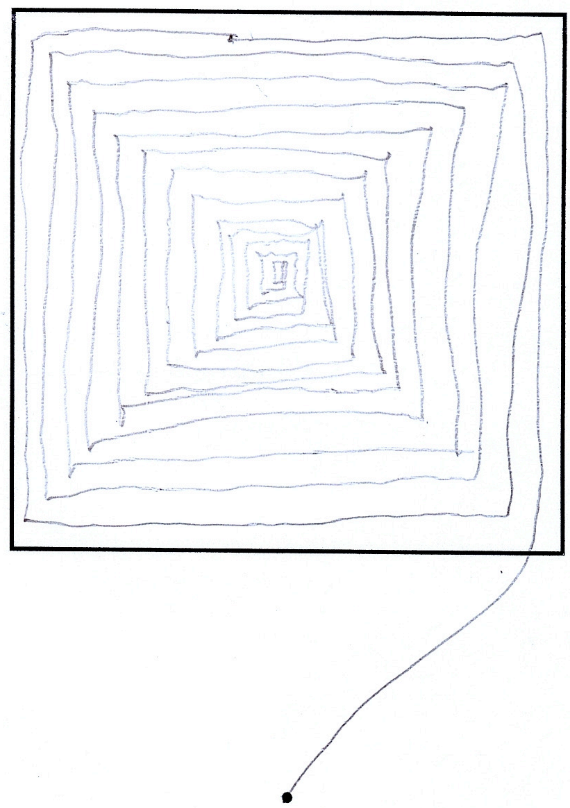
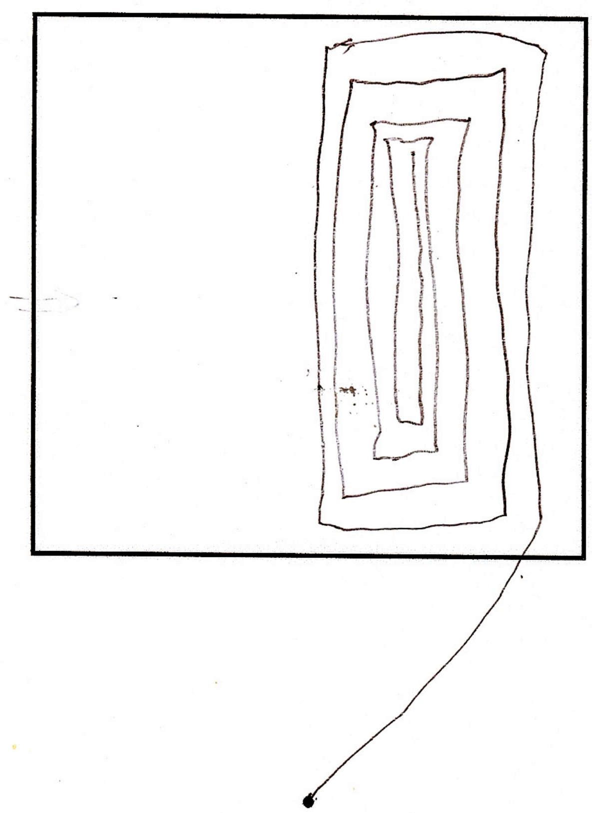


Figure 4. Performance on key search task by FH from the perspective of the third person.



Discussion

In the the Key Search task (BADS; Wilson et al., 1996), two stroke patients performed the task from a first and third person perspective. The results of the task suggest that perspective taking could affect the way that participants perform the task, thus highlighting a social component of the task. Taking another person perspective requires numerous skills, such as how a person would behave or act in a particular situation, such as search for the key. Moreover, it also requires a separate understanding between the concept of 'self' and others. FH performed very well on the key search task in the 1st person perspective, but his performance was poorer when he was asked to search for the key for John, where he searched only half of the field. In contrast, CW performed very well in searching for the lost key from a 3rd person perspective, but poorer in the 1st person. It should be stressed that the poorer performance by CW on the task in the 1st person was not due to failure in the concept of the self (as he had knowledge about himself, his abilities, personality traits etc) but rather abstract reasoning, i.e. grasping the concept that he would not know where he lost the key

The perspective taking examples demonstrate the social sensitivity of the key search task. The social neuroscience literature suggests that the brain regions mostly associated with perspective taking (1st and 3rd person) are located in distinct regions of medial prefrontal cortex (e.g. D'Argembeau et al., 2007). It would be interesting to look at the brain regions specifically recruited during the process of planning and executing the key search task for oneself and for others (John).

Appendix 14: Published paper from this thesis

EFFECTS OF AGE ON CROSS-MODAL EMOTION PERCEPTION.

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Effects of Age on Cross-Modal Emotion Perception

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Efficient navigation of our social world depends on the generation, interpretation, and combination of social signals within different sensory systems. However, the influence of healthy adult aging on multisensory integration of emotional stimuli remains poorly explored. This article comprises 2 studies that directly address issues of age differences on cross-modal emotional matching and explicit identification. The first study compared 25 younger adults (19–40 years) and 25 older adults (60–80 years) on their ability to match cross-modal congruent and incongruent emotional stimuli. The second study looked at performance of 20 younger (19–40) and 20 older adults (60–80) on explicit emotion identification when information was presented congruently in faces and voices or only in faces or in voices. In Study 1, older adults performed as well as younger adults on tasks in which congruent auditory and visual emotional information were presented concurrently, but there were age-related differences in matching incongruent cross-modal information. Results from Study 2 indicated that though older adults were impaired at identifying emotions from 1 modality (faces or voices alone), they benefited from congruent multisensory information as age differences were eliminated. The findings are discussed in relation to social, emotional, and cognitive changes with age.

Keywords: aging, emotion perception, multisensory integration

In everyday situations our brain integrates information from multiple sensory signals to enhance perception and guide our behavior. When information from multiple sensory signals is congruent, this facilitates behavior, resulting in faster response times and increased accuracy (Calvert, Spence, & Stein, 2004; Forster, Cavina-Pratesi, Aglioti, & Berlucchi, 2002; Hughes, Reuter-Lorenz, Nozawa, & Fendrich, 1994). However, the need to integrate incongruent stimuli from different sensory modalities can impair the ability to process information (Calvert et al., 2004; Meredith & Stein, 1986, 1996; Stein & Merdich, 1993). So far, little is known about whether there are age effects in processing congruent and incongruent audiovisual information. It had been suggested that older adults benefit more than do younger adults from simultaneous presentation of semantically congruent multisensory information (Laurienti, Burdette, Maldjian, & Wallace, 2006). In the current study, we investigate whether this benefit for older adults from multiple channels of information extends to emotionally salient cues.

Successful social interaction in everyday situations requires individuals to orchestrate information received through multiple sensory channels such as emotional visual cues from faces and gestures and emotional prosody from voices (Russell, Bachorowski, & Fernandez-Dols, 2003). Relatively few studies have investigated integration of emotional cues presented in the audio and visual channels (see Campanella & Belin, 2007; Collignon et al., 2008). Nevertheless, it has been postulated that congruence between facial emotion and voice prosody facilitates reactions to stimuli (e.g., de Gelder & Vroomen, 2000; Ethofer, Pourtois, & Wildgruber, 2006). For instance, congruent cross-modal presentation of a fearful voice facilitates recognition of a fearful facial expression (de Gelder, Dolan, & Morris, 2001). However, our knowledge of whether multisensory processes related to social stimuli are influenced by aging remains limited. Most aging studies have focused on the processing of emotional cues only in the visual modality (Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006) or in the auditory modality (Allen & Brosgole, 1993). Key results indicate that older adults are less able to distinguish different negative emotions via unimodal visual and auditory channels than are younger adults (Brosgole & Weisman, 1995; MacPherson, Phillips, & Della Sala, 2006; Phillips, MacLean, & Allen, 2002; Ruffman, Henry, Livingstone, & Phillips, 2008; Wong, Cronin-Golomb, & Neargarder, 2005). In particular, older adults show difficulty in identifying anger, sadness, and fear from faces, as well as identifying prosodic expressions of anger and sadness (for a review, see Ruffman et al., 2008).

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One of the hypotheses for older adults' poor performance on negative emotion identification is that older adults through a lifetime of experience in monitoring and regulating emotions have developed a bias to attend away from negative information and instead focus on the positive (see Carstensen, Fung, & Charles, 2003; Carstensen & Mikels, 2005; Mather & Carstensen, 2003). There are also other possible explanations for the pattern of emotion perception difficulties of older adults, such as cognitive and neuropsychological changes (Ruffman et al., 2008).

In the current study our main focus is on the effects of aging on cross-modal emotion perception. But in order to investigate whether there are differential age effects on unimodal and cross-modal emotion processing, we also look at age-related differences in identification of emotions only from faces and only from voices. This will also allow comparison of our study with other studies of age differences in emotion perception in the literature. Most of the auditory affective stimuli previously used carry linguistic content (Monrad-Krohn, 1963), which might interact with identification of affective prosody. In the current study our prosodic stimuli comprise nonverbal affective bursts (Belin, Fillion-Bilodeau, & Gosselin, 2008), which are less likely to be subject to interference between semantic content and prosody judgments.

Our everyday experience of decoding emotions from other people generally involves a simultaneous combination of visual and auditory cues, and it remains unexplored whether simultaneous presentation of auditory and visual cues to emotion benefits affects recognition performance in older adults. One previous study investigated age differences in the ability to match emotional faces to voices and found that matching emotional sounds to angry, sad, and disgusted faces proved to be more difficult for older adults than in younger adults (Sullivan & Ruffman, 2004). However, Sullivan and Ruffman (2004) used a methodology in which participants heard an emotional sound (a passage read in an emotional tone or a nonverbal expressive sound) that lasted for 20 s. Once the sound stopped, participants then had to match the sound to one of six different facial emotions presented on a computer screen. In our cross-modal studies, participants had to match whether emotional stimuli presented on the face and in the voice were the same or different (Study 1) and identify which emotion was being presented from single and bimodal channels (Study 2). Given evidence from nonemotional stimuli that older adults may be able to compensate for problems in processing single-modality stimuli through multisensory integration (Laurienti et al., 2006), the current study aimed to explore whether older adults benefit from congruent multisensory information about emotions.

Study 1

Cross-modal information is beneficial to processing only when the information presented in both modalities is congruent. When the information from one modality contradicts the other, this compromises processing of the target information, resulting in slower reaction times and lower accuracy (Meredith & Stein, 1986, 1996). This pattern also occurs when incongruent audiovisual information relates to emotional stimuli, as for instance, perception of facial emotional expression can be altered by vocal information representing a different emotion (Ethofer et al., 2006; Kreifelts et al., 2007). Understanding age effects on the processing of congruent and incongruent visual and auditory emotional information will shed more light on social processing in older adults. For instance, it is important to be able to judge whether cross-modal information is congruent, because it is an indicator that emotion portrayed in both channels is genuine, whereas problems in detecting incongruence might indicate lack of sensitivity to identify deceit.

Hence, the first study directly addresses age differences on an emotional cross-modal matching task in which participants hear and see emotional information simultaneously from faces and voices and must decide whether the information is congruent or incongruent. In addition to a cross-modal matching task, participants also identified emotions presented only on the faces and in the voice. We predict that on both unimodal emotion identification tasks, older adults would perform more poorly than would younger adults on negative emotion identification, in line with the aging literature described above. In addition, we predicted that older adults would perform as well as younger adults on congruent matching tasks in which both auditory and visual emotional information were presented concurrently, as they would benefit from multisensory integration. However, given well-documented difficulties with controlled inhibition of irrelevant information in older adults (Hasher & Zacks, 1988), older adults were predicted to perform more poorly than younger adults on the cross-modal incongruent trials.

Method

Participants. Fifty healthy volunteers were recruited through the volunteer database held at the University of Edinburgh: 25 younger adults (9 men and 16 women) ages between 18 and 40 years with a mean age of 22.64 years ($SD = 5.86$) and 25 older adults (15 men and 10 women) ages between 60 and 79 with a mean age of 66.96 years ($SD = 6.10$). All participants were right-handed. They performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997) to assess speed of processing. Older and younger adults did not significantly differ in years of education ($M = 15.40$, $SD = 3.67$, and $M = 15.08$, $SD = 2.25$, respectively), $t(48) = -.37$, $p = .712$, or verbal ability ($M = 113.88$, $SD = 5.94$, and $M = 111.24$, $SD = 5.31$, respectively), $t(48) = -1.66$, $p = .104$. However, in terms of speed of processing, older adults were significantly slower than were younger adults ($M = 51.20$, $SD = 10.10$, and $M = 67.76$, $SD = 10.91$, respectively), $t(48) = 5.57$, $p < .001$. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the Wechsler Adult Intelligence Scale—III UK selection criterion (Wechsler, 1997).

Emotional stimuli.

Unimodal facial emotion identification. The ability to recognize emotional expressions from faces was tested using the Facial Expressions of Emotion: Stimuli and Test (FEEST; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). Sixty black-and-white photographs of faces displaying one of the six basic emotions (happiness, surprise, fear, sadness, disgust, or anger) were shown, one at a time, in the middle of a computer screen. Participants were instructed to choose which of the six labels best described the emotion displayed on each face. Photographs were presented in a pseudorandom order, and 10 examples of each emotion were displayed. The faces were shown for a period of 5 s each, but participants could take as long as they wished to decide on the emotion and no feedback was given about the accuracy of a participant's choices. The task started with six practice trials. The dependent variable was percentage accuracy for each emotion.

Unimodal prosodic emotion identification. Auditory affective stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, Pennsylvania) and were presented through headphones. The prosodic emotional stimuli were taken from the Montreal Affective Voices (Belin et al., 2008), which take the form of short nonlinguistic interjections of the vowel /a/. The set contained a series of nonverbal affective emotions (anger, disgust, fear, happiness, sadness, and surprise). In the current paradigm the prosodic stimuli were presented for no longer than 450 ms. Four female voices and four male voices were used, all portraying an example of each emotion. Therefore, each vocal emotion (anger, disgust, fear, happiness, sadness, and surprise) was presented eight times, giving a total of 48 trials. Prior to performing the task, participants performed six practice trials. For each trial, participants decided whether the interjection was most like happiness, sadness, surprise, fear, disgust, or anger. No feedback was given. Participants could take as long as they wished to decide on the emotion. The stimuli were presented in random order. The dependent variable was percentage accuracy.

Cross-modal emotion matching. For this auditory and visual cross-modal paradigm, the series of faces adopted from FEEST (Young et al., 2002) and the prosodic emotional stimuli from Montreal Affective Voices (Belin et al., 2008) were used as described above. Participants were presented with an emotional expression on a face at the same time as a prosodic emotional interjection. Emotional faces (2 male and 2 female faces) taken from FEEST (Young et al., 2002) were paired with actors' voices (2 male and 2 female voices) from the Montreal Affective Voices (Belin et al., 2008) in a way that a particular face always appeared with same gender corresponding prosodic expression.

In the congruent trials, six facial emotions (anger, fear, disgust, sadness, happiness, and surprise) were paired with matching corresponding prosodic expressions—for instance, "happy"–happy, "sad"–sad. Face–voice pairings for each of the six emotions were repeated four times, giving a total of 24 congruent trials. In the audiovisual incongruent trials, the same six facial emotions were presented four times, but with a nonmatching prosodic expression—for example, "happy"–sad—giving again a total of 24 incongruent trials. In the incongruent trials, the facial emotion–prosodic expression pairings were different each time. Each negative emotion presented on the face (fear, sadness, disgust, and anger) was paired once with happiness and once with surprise (in other words, once each with the two positive emotions) and paired in the remaining two trials with two of the other negative emotions (randomly allocated). Positive emotions presented on the face (happiness and surprise) were paired once each with the four negative emotions (disgust, sadness, anger, and fear) presented in the voice. Each emotional voice in the incongruent face–voice pairings was presented four times across all the trials. Following the methods of previous experiments in this field of multisensory congruence detection (e.g., Laurienti, Kraft, Maldjian, Burdette, & Wallace, 2004), we also included some control trials. In these control trials, six facial emotions (anger, fear, disgust, sadness, happiness, and surprise) were presented without a prosodic stimulus and were repeated four times, giving a total of 24 control trials.

In order to be comfortable with the task, participants performed six practice trials. The stimuli were delivered by E-Prime Software (Psychology Software Tools, Pittsburgh, Pennsylvania). The visual stimuli were presented in the middle of a computer screen, and the auditory stimuli were presented through headphones. Each trial started with a 2-s fixation cross in the center of the screen. The audiovisual stimuli were then presented in synchrony, during which the visual stimuli were presented for a maximum of 1000 ms and the auditory stimuli were presented for no longer than 450 ms. Participants were asked to attend to the emotional expression on the face and identify whether the audiovisual stimuli were congruent, incongruent, or face-only control trials by pressing an appropriate response button, responding as quickly and accurately as possible. The dependent variable was the percentage accuracy for each condition. The order of the stimuli was randomized.

Procedure. Participants performed the three tasks (facial, prosodic, and cross-modal); the order of these tasks was counterbalanced across participants. In each of the tasks the sound level was adjusted to be comfortable for each participant, and participants were seated approximately 50 cm from the visual display.

Results

Unimodal facial emotion identification. A mixed 2 (age: young and old) × 6 (emotions: anger, fear, disgust, sadness, happiness, and surprise) analysis of variance (ANOVA) was conducted on percentage correct identifications of facial expressions of emotion; see Table 1 for descriptive information. There was a main effect of emotion, $F(5, 240) = 18.03$, $p < .001$, $\eta_p^2 = .273$. Pairwise comparisons with Bonferroni adjustment revealed that emotion of happiness was significantly better identified than were all other emotions, such as anger ($p < .001$), fear ($p < .001$), sadness ($p < .001$), disgust ($p < .001$), and surprise ($p < .001$). There was also a main effect of age, $F(1, 48) = 29.25$, $p < .001$,

Table 1
Mean Percentage Accuracy and Standard Deviations for Younger and Older Adults Performing the Unimodal Facial and Prosodic Emotion Identification Tasks (Experiment 1)

Task	Younger adults (n = 25)		Older adults (n = 25)	
	M	*SD*	*M*	*SD*
Facial emotion recognition				
Happiness	99.20	2.77	96.80	7.48
Surprise	88.80	9.71	80.80	13.51
Fear	79.60	16.70	68.80	18.10
Sadness	88.40	13.44	74.80	15.84
Disgust	84.80	14.18	83.20	13.45
Anger	86.00	10.40	71.60	17.24
Prosodic emotion recognition				
Happiness	93.12	11.95	94.08	10.80
Surprise	58.76	21.86	62.72	17.24
Fear	84.64	13.63	63.76	21.59
Sadness	96.08	9.22	84.48	21.48
Disgust	90.08	11.39	75.16	10.21
Anger	78.68	16.65	49.76	20.53

$\eta_p^2 = .379$, for which older adults performed significantly more poorly than did younger adults. The interaction between age and emotion that approached significance, $F(5, 240) = 2.10$, $p = .066$, $\eta_p^2 = .042$, suggests that this age effect is driven by negative emotions. Therefore, we decided to conduct a further analysis using independent samples t tests to explore age differences on each emotion. The results suggest that younger adults performed significantly better than did older adults on identification of anger, $t(48) = 3.57$, $p < .001$; sadness, $t(48) = 3.27$, $p = .002$; surprise, $t(48) = 2.40$, $p = .020$; and fear, $t(48) = 2.19$, $p < .033$; but not happiness, $t(48) = 1.50$, $p = .139$; and disgust, $t(48) = .41$, $p = .684$.

Unimodal prosodic emotion identification. Descriptive information for this task is also shown in Table 1. A 2 (age: young and old) × 6 (emotions: anger, fear, disgust, sadness, happiness, and surprise) ANOVA was conducted on percentage of correct responses. There was a main effect of age, $F(1, 48) = 33.8$, $p < .001$, $\eta_p^2 = .414$, and further analysis showed that older adults performed significantly more poorly than did younger adults on negative prosodic emotion identification. There was also a main effect of emotion, $F(5, 240) = 36.09$, $p < .001$, $\eta_p^2 = .429$. Results of pairwise comparisons with Bonferroni correction suggest that the vocal emotion of happiness was significantly easier to identify than were anger ($p < .001$), fear ($p < .001$), disgust ($p < .001$), and surprise ($p < .001$). Among negative prosodic emotions, anger was significantly more difficult to recognize than were sadness ($p < .001$) and disgust ($p < .001$). The interaction between group and emotion was significant, $F(5, 240) = 7.84$, $p < .001$, $\eta_p^2 = .140$. Independent sample t tests indicated that older adults performed more poorly in recognizing negative emotions from voice prosody than did younger adults: anger, $t(48) = 5.47$, $p < .001$; fear, $t(48) = 4.09$, $p < .001$; disgust, $t(48) = 4.88$, $p < .001$; and sadness, $t(48) = 2.48$, $p < .017$; but there were no age differences for happiness, $t(48) = -.30$, $p = .77$, and surprise, $t(48) = -.71$, $p = .481$.

Cross-modal emotion matching. The percentage of correct responses for each age group (young vs. old) in each of the conditions (congruent, incongruent, and control) are illustrated in Figure 1. A mixed 2 (age) × 3 (condition) ANOVA was conducted on the percentage of correct responses.

There was a main effect of age, $F(1, 48) = 33.87$, $p < .001$, $\eta_p^2 = .414$, with older adults performing significantly more poorly than did younger adults. The results also showed that there was a main effect of condition, $F(2, 96) = 101.39$, $p < .001$, $\eta_p^2 = .679$, and pairwise comparisons with Bonferroni adjustment revealed that the congruent condition was more accurately performed than the incongruent condition ($p < .001$). However, the face-only control condition had a higher accuracy rate than did the congruent condition ($p < .001$) or the incongruent condition ($p < .001$). The interaction of age and condition was also significant, $F(2, 96) = 27.78$, $p < .001$, $\eta_p^2 = .367$. Independent-sample t tests revealed that younger and older adults did not significantly differ in matching faces to voices either in the congruent condition, $t(48) = -.54$, $p = .593$, or in the face-only control condition, $t(48) = .71$, $p = .483$. However, in the incongruent condition, younger adults performed significantly better than did older adults, $t(48) = 6.26$, $p < .001$. Note that because incongruent trials involved many different pairings of emotions, we did not have sufficient statistical power to investigate an Age × Emotion interaction for this task.

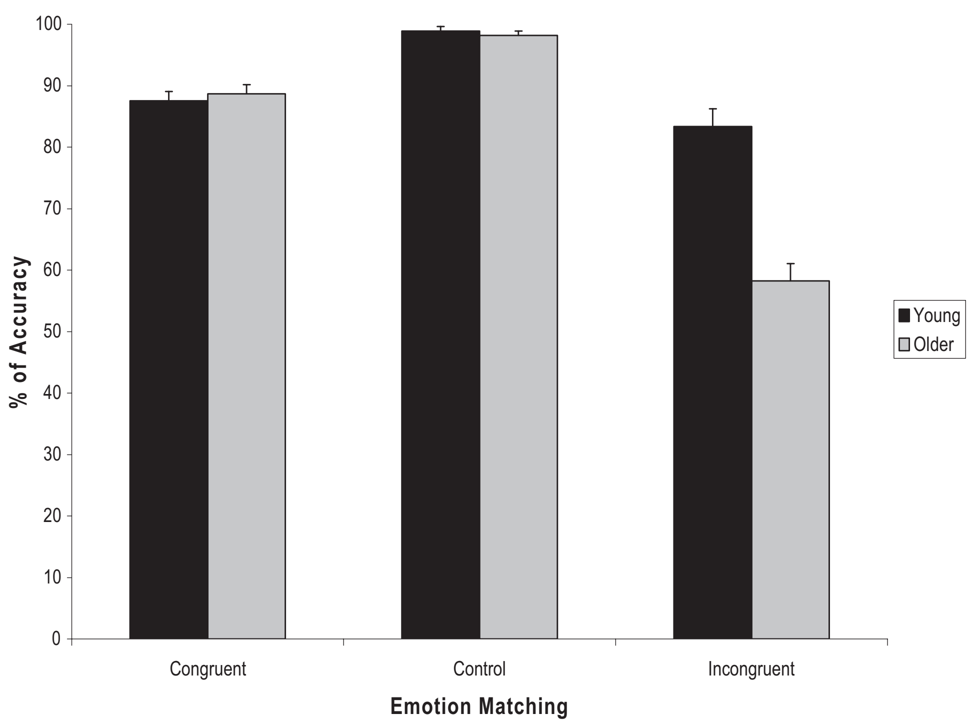

Figure 1. Percentage accuracy scores for both age groups performing the cross-modal emotion-matching task (Experiment 1). Error bars indicate standard errors of the mean.

In order to ensure that older adults did not simply perform well on the congruent condition because of a bias toward pressing the congruent response button when performing the task, we measured the response bias (criterion β) and sensitivity (d') using signal detection theory (for a review, see Swets, 1996) on the congruent and incongruent trials. Older and younger adults did not significantly differ in terms of response bias (M = 1.98, SD = .86, and M =1.45, SD = 1.12, respectively), $t(48) = -1.82$, $p = .074$, and therefore there is no age-related bias in responding to the stimuli. However, there was a significant difference between younger and older adults in the sensitivity parameter d' (M = 2.25, SD = .38, and M =1.46, SD = .55, respectively), $t(48) = 5.89$, $p < .001$, suggesting that younger adults were more sensitive in discriminating the difference between congruent and incongruent stimuli than were older adults.

Discussion

The overall findings support our prediction that older adults would perform as well as younger adults in matching faces to voices in the congruent emotion condition but would be impaired in the incongruent emotion condition. Also, the results from both unimodal identification tasks supported previous results (e.g., Ruffman et al., 2008), suggesting that older adults might find identifying negative emotions more challenging than would younger adults. These results suggest that, in line with findings for nonemotional stimuli (Laurienti et al., 2006), older adults may benefit from cross-modal emotional information when both modalities are congruent. In contrast, older adults had particular difficulty in identifying when two sources of emotional information are incongruent, which may link to more general difficulties in processing conflicting information in old age.

The results from the unimodal tasks indicated that older adults performed significantly more poorly in the identification of emotions in auditory and visual channels. For visual information, older adults performed more poorly than did younger adults in identifying emotions of fear, sadness, surprise, and anger from faces, similar to evidence from previous emotion identification studies (MacPherson et al., 2006; Phillips et al., 2002; Ruffman et al., 2008). Younger and older participants were also asked to label prosodic expressions. There are a number of studies that aimed to establish whether there is an age-related decline in identification of vocal expression (Mitchell, 2007; Orbelo, Grim, Talbott, & Ross, 2005; Raithel & Hielscher-Fastabend, 2004), but only a few studies have looked at the individual emotions separately (Brosgole & Weisman, 1995; Wong et al., 2005). Wong et al. (2005) found that older adults performed worse on identification of auditory expressions of sadness and happiness, but not auditory expressions of anger, fear, disgust, and surprise. In contrast, Brosgole and Weisman (1995) found an age-related reduction in recognition of anger, sadness, and happiness. Our results indicate that older adults show difficulty in identifying negative emotions of fear, anger, sadness, and disgust. This diverse pattern of findings across aging studies in voice prosody might be due to the fact that researchers use different prosodic stimuli, some of which carry linguistic content that might influence emotion recognition.

The current study cannot directly test for a positivity bias in age differences in processing emotional information (Carstensen & Mikels, 2005), because we used the six basic emotions common to most studies that include only two possible positive emotions. Surprise is often considered as a positive emotion but it can also act as a negative emotion if someone is surprised in an unpleasant manner (Ruffman et al., 2008). Only happiness can be treated as nonambiguous positive emotion, but here, younger and older adults performed at ceiling on both tasks related to identification of happiness from either faces or voices, as is usually the case. In order to look at age-related positivity biases in relation to emotion perception, it would be necessary to use different types of emotional stimuli rather than the six basic emotions that are used in the majority of studies (e.g., varying types of smile; see Slessor, Miles, Bull, & Phillips, 2010).

The finding from Study 1 that older adults perform well in matching congruent emotional information across different modalities fits with the hypothesis that older adults can benefit from congruent multisensory information (Laurienti et al., 2006). One important issue that cannot be addressed by the current data is whether the provision of cross-modal information might help older adults to explicitly identify emotions in comparison with the situation in which only a single modality of information is available. This is the topic of the next study.

Study 2

The second study investigates whether older adults benefit from cross-modal information in explicit emotion identification. Given ceiling levels in performance on positive emotions, we used only negative emotional stimuli, that is, sadness, disgust, fear, and anger. The hypothesis in the current experiment was that older adults would perform as well as younger adults in identifying emotions when bimodal presentations of congruent faces and voices were presented at the same time. This should contrast with performance that is poorer than that of younger adults when emotions were presented only in one modality, that is, faces and voices on their own.

Method

Participants. Forty right-handed healthy volunteers were recruited through the volunteer databases held at the University of Edinburgh and the University of Aberdeen: 20 younger adults (8 men and 12 women), ages between 18 and 23 years with a mean age of 20.00 years (SD = 1.48) and 20 older adults (10 men and 10 women), ages between 63 and 78 years with a mean age of 70.55 years (SD = 4.12). All participants performed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an assessment of verbal ability and the digit symbol substitution subtest (DSST) from the Wechsler Adult Intelligence Scale (Wechsler, 1997). Older and younger adults did not significantly differ in their verbal ability (M = 108.50, SD = 5.58, and M =111.15, SD = 4.05, respectively), $t(38) = 1.72$, $p = .094$. However, in terms of speed of processing, older adults performed significantly slower than did younger adults (M = 44.60, SD = 10.34, and M =64.35, SD = 10.15, respectively), $t(38) = 6.09$, $p < .001$. English was the first language of all participants. None of the participants had any history of neurological or psychiatric disorders as listed in the

Wechsler Adult Intelligence Scale—III UK selection criterion (Wechsler, 1997).

Materials and procedure. A cross-modal paradigm was devised using visual and auditory emotional information. The visual stimuli were taken from the Ekman and Friesen (1975) series of 10 faces (5 male faces and 5 female faces), portraying four negative emotions: fear, disgust, sadness, and anger.[1] The corresponding prosodic emotional stimuli for anger, sadness, fear, and disgust were adopted from Montreal Affective Voices (Belin et al., 2008), which take the form of short nonlinguistic interjections of the vowel /a/. Participants were asked to identify which emotion was portrayed on the face, in the voice, or face and voice combined together by pressing *A* for anger, *S* for sadness, *D* for disgust, or *F* for fear. The visual stimuli were presented for maximum of 1000 ms, and auditory stimuli were presented for no longer than 450 ms, as in the previous experiment.

The audiovisual stimuli were presented in synchrony (Stimulus Onset Asynchrony = 0 ms), and emotion presented on the face matched the emotion presented in the voice. The paradigm contained 40 pairs of emotions presented cross-modally, 40 emotions presented visually, and 40 auditory emotions, giving a total of 120 trials. Therefore, in each of the conditions—visual, auditory, or audiovisual—each emotion (anger, sadness, disgust, and fear) was presented 10 times. Participants were instructed to respond as quickly and accurately as possible. The sound level was adjusted to be comfortable for each participant, and participants were seated approximately 50 cm from the visual display. Prior to performing the task, participants performed eight practice trials. The dependent variables were the percentage accuracy for each type of trial—that is, audio-visual, visual only, and auditory only. Participants completed a single block of trials, including visual, auditory, and audiovisual trials. The order of the stimuli was completely randomized.

Results and Discussion

A mixed 2 (age: young and old) × 3 (condition: audiovisual, visual only, and auditory only) × 4 (emotions: fear, sadness, disgust, and anger) ANOVA was conducted on the percentage of correct responses. Descriptive information for this task is shown in Table 2.

The analysis showed that there was a main effect of age, $F(1, 38) = 11.15$, $p = .002$, $n_p^2 = .227$, indicating that older adults performed significantly more poorly than did younger adults. This main effect is qualified by the Age ×Condition interaction. There was also a main effect of condition, $F(2, 76) = 46.68$, $p < .001$, $n_p^2 = .551$. Pairwise comparisons with Bonferroni correction showed that audiovisual emotions were easier to recognize than were emotions presented separately on the faces ($p < .001$) or in the voices ($p < .001$). Also, participants found identifying emotions to be significantly easier from faces than from voices ($p < .001$). There was also a main effect of emotion, $F(3, 114) = 33.90$, $p < .001$, $n_p^2 = .472$. Pairwise comparisons with Bonferroni adjustment indicated that sadness and disgust were better recognized than were fear ($p < .001$ and $p < .002$, respectively) and anger ($p < .001$). However, fear was better recognized than was anger ($p < .002$).

The interaction between age and condition was also significant, $F(2, 76) = 4.97$, $p < .009$, $n_p^2 = .116$. Further analysis using

Table 2
Means and Standard Deviations for Older and Younger Adults Performing the Cross-Modal Emotion Recognition Task (Experiment 2)

Task	Younger adults ($n = 20$)		Older adults ($n = 20$)	
	M	*SD*	*M*	*SD*
Facial emotion recognition (faces only)				
Fear	95.75	7.48	88.50	14.96
Sadness	89.00	11.65	84.50	17.91
Disgust	96.25	5.82	89.00	13.34
Anger	84.25	14.07	76.50	14.24
Prosodic emotion recognition (voices only)				
Fear	81.75	17.11	67.00	21.78
Sadness	98.75	3.19	94.50	9.44
Disgust	96.00	8.20	82.50	14.82
Anger	69.25	20.27	60.50	25.02
Facial and prosodic emotion recognition (faces and voices)				
Fear	95.00	8.88	91.00	15.86
Sadness	97.00	7.33	93.00	7.33
Disgust	98.50	3.66	94.50	7.59
Anger	84.25	14.98	83.50	14.96

independent-sample *t* tests revealed that older adults performed as well as younger adults on the emotion recognition task when emotions were presented via auditory and visual modality at the same time, $t(38) = 1.58$, $p = .123$. However, older adults performed significantly more poorly than did younger adults on emotion recognition from faces only, $t(38) = 2.55$, $p = .015$, and from voices only, $t(38) = 3.84$, $p < .001$). See Figure 2 for descriptive information.

There was also a significant interaction between condition and emotion, $F(6, 228) = 11.72$, $p < .001$, $n_p^2 = .236$. Further analysis with Bonferroni correction for multiple comparisons revealed that in the audiovisual condition, anger was more poorly recognized than were fear ($p = .038$), sadness ($p < .001$), and disgust ($p < .001$). Also, in the picture-only condition, anger had lower recognition than did fear ($p < .001$) and disgust ($p < .001$). In contrast, in the auditory-only condition, anger was better recognized than were fear ($p < .001$), sadness ($p = .003$), and disgust ($p < .001$), and participants found it easier to identify sadness than fear ($p < .001$) and disgust ($p < .001$). The two-way interaction between emotion and age, $F(3, 114) = .620$, $p < .604$, $n_p^2 = .016$, and three-way interaction between condition, emotion, and age, $F(6, 228) = 4.78$, $p < .824$, $n_p^2 = .012$, were not significant.

Overall the results of the study support our experimental hypothesis, because older adults benefitted from congruent multisensory information in interpreting emotions. There were no age differences in the cross-modal condition, but older adults per-

[1] In Study 1 we used Ekman & Friesen's (1975) set of six basic emotions. As other research within the field (e.g., Ruffman et al., 2008) as well as our results from Study 1 report ceiling performance on positive emotion recognition from faces, we decided to include only negative emotions in Study 2.

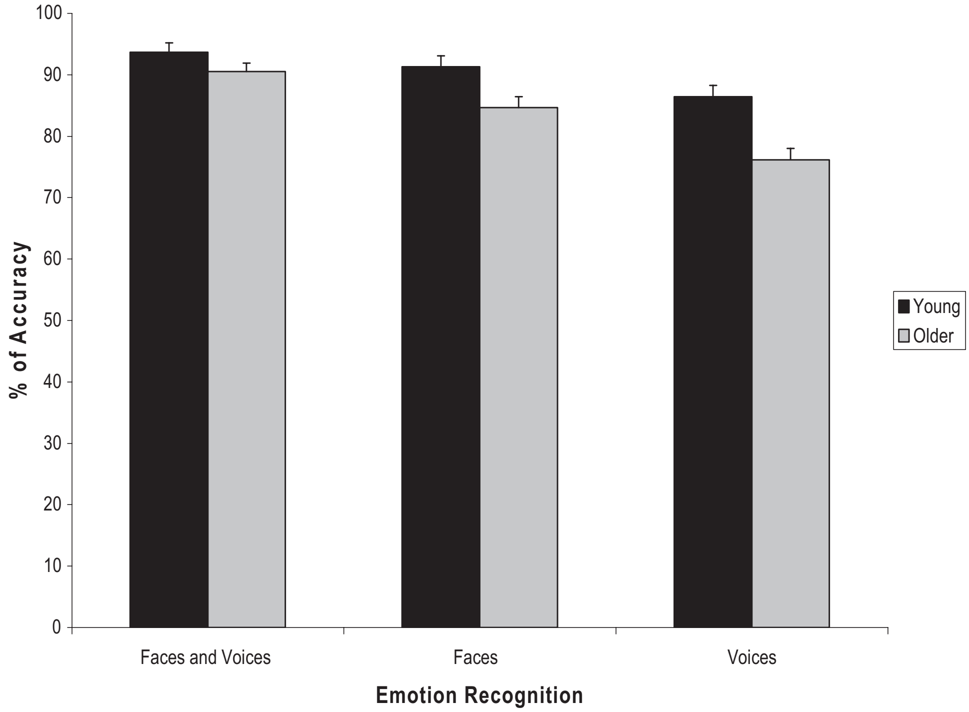

Figure 2. Percentage accuracy scores for both age groups performing the cross-modal emotion recognition task (Experiment 2). Error bars indicate standard errors of the mean.

formed worse than did young adults in conditions in which emotions were presented only in one modality, that is, only faces and only voices.

General Discussion

Across two studies we found clear evidence that older adults had difficulty in identifying emotions from faces and voices, in line with previous findings (Ruffman et al., 2008). Our novel hypothesis was that these age differences in emotion perception would disappear when congruent multimodal information was available. Evidence to support this hypothesis was found in two studies. Older adults were as good as young adults at detecting congruence in cross-modal emotional cues (Study 1) and explicitly identifying emotions from cross-modal cues (Study 2). Taken together, this evidence indicates that older adults benefit substantially from the provision of multiple channels of information about emotions. Good ability to use congruent sources of information about emotions may benefit older adults in social situations, in which more than one modality of information will usually be available.

Our results extend to emotional information regarding the finding that older adults can benefit from congruent multisensory information in processing nonemotional stimuli (Laurienti et al., 2006). Although it remains unclear why older adults benefit more than do younger adults from multisensory integration, it was initially suggested that it might be caused by age-related changes in modulation of attention (Alain & Woods, 1999; Laurienti et al., 2006; Peiffer , Mozolic, Hugenschmidt, & Laurienti, 2007). When younger adults are presented with cross-modal information and attend to one modality, their neural activity of attended modality is enhanced, but neural activity of the irrelevant modality is significantly decreased. In contrast, because older adults show less suppression of cross-modal information, it was proposed that they have enhanced multisensory integration. However, recent findings of Hugenschmidt, Peiffer, McCoy, Hayasaka, and Laurienti (2009) indicate that enhanced multisensory integration in older adults may not be due to the deficits in cross-modal selective attention. An alternative explanation views multisensory enhancement in older adults as a form of compensatory strategy for age-related reduction of brain activity of sensory cortex responding to a single modality (Cabeza, Anderson, Locantore, & McIntosh, 2002; Peiffer et al., 2007).

We also hypothesized that older adults might have difficulty in perceiving incongruency from across different emotional channels, and this was supported by the results of Study 1. Poor ability to perceive incongruent emotions from different sensory modalities might impair older adults' ability to understand cues to deception or masking of emotions. The poorer performance of older adults in incongruent cross-modal conditions might be explained in terms of neuropsychological models of aging, which postulate that cognitive changes in older adults are due to deterioration of the frontal lobes (e.g., Moscovitch, & Winocur, 1995). More recently, MacPherson, Phillips, and Della Sala (2002) proposed a dorsolateral prefrontal theory of cognitive aging in which age effects are found on cognitive abilities tapping the dorsolateral prefrontal cortex (DLPFC), such as working memory and executive abilities (MacPherson et al., 2002; Terry, DeTeresa, & Hansen, 1987). The poorer understanding of cross-modal conflicting emotional cues in older adults may reflect age declines in cognitive abilities tapping the DLPFC, given evidence for the role of DLPFC in incongruent cross-modal matching (Plaza, Gatignol, Cohen, Berger, & Duffau, 2008). Plaza et al. (2008) looked at involvement of DLPFC in a congruent/incongruent cross-modal task while conscious during brain surgery. In Plaza's task, patients had to identify whether pictures and spoken words were semantically congruent or incongruent. The results indicate that when patients were receiving electrical stimulation to DLPFC, they made significantly more errors in the incongruent (but not congruent) picture–word matching condition. It would be interesting in future research to explore the role of DLPFC in dealing with emotionally incongruent information in both younger and older adults.

Future research within the area should address effects of type of emotion on cross-modal perception with relation to age positivity bias proposed by Carstensen and Mikels (2005). This would require the development of new tasks to assess distinctions between different positive emotions, or methods of assessing attention to positive and negative information rather than reliance on accuracy of matching and labelling emotions. Another important factor to consider in future research includes the different ways in which auditory emotions can be portrayed. As is highlighted above, the results from aging studies on auditory emotion perception are not very consistent, and it would be useful to have a clearer comparison of age differences in identifying emotions from spoken semantic context, speech prosody (in which content is neutral), and nonverbal emotional utterances. In addition, it is important to consider gender differences, because the study of Collignon et al. (2010) found that women tend to integrate multisensory emotional stimuli more efficiently than do men. The current study does not have sufficient power to fully address gender differences.

In conclusion, in unimodal paradigms related to facial and prosodic emotion identification, we found that older adults performed more poorly than did younger adults. However, in a task in which participants had to match emotional faces to voices, older adults performed as well as did younger adults when presented with congruent auditory and visual emotional information, but had difficulty in identifying incongruent information. Finally, older adults performed as well as did younger adults on congruent explicit cross-modal emotion identification. The results therefore show that older adults may benefit from congruent multisensory information when interpreting emotions.

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